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Design-Makers Guide in Solid Waste Management

Environmental Protection Agency

1974

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This guide presents the key issues of solid waste management in a decision-making context. It attempts to anticipate all of the important decisions which local government managers must make in the effort to develop and operate solid waste programs in a responsive, cost-effective manner. Each chapter presents an issue, describes the alternatives, gives the advantages and disadvantages, and concludes with a summary statement which may include an EPA recommendation on the issue. Four basic categories of criteria by which decisions are made in this field are the following: costs, environmental factors, resource conservation, and institutional factors.

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Water pollution,
Esthetics,
Fuels,
Materials recovery,
Land use,
Legislation,
Financing,
Collection,
Separation,
Manpower,
Transportation,
Sanitary landfills,
Decision making,
Tires,
Lubricating oils,
Paper,
Plastics,
Sludge disposal,
Hazardous materials,
Incentives,
Baling,
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This guide (SW-127) was prepared under the direction of
ROBERT A. COLONNA and CYNTHIA McLAREN
of the Office of Solid Waste Management Programs

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Foreword

The purpose of the *Decision-Makers Guide in Solid Waste Management* is to help managers in municipal government deal with the problems of major concern in the field of solid waste management. This document was prepared under the authority of Section 209(b)(2) of the Solid Waste Disposal Act of 1965, as amended by the Resource Recovery Act of 1970. It includes guidelines on organization and financing of services, waste collection, processing, disposal, and recovery of energy and materials.

In solid waste management, as in other aspects of city administration, good decision-making is nearly synonymous with good city management. In the past, however, decisions regarding solid waste management have been based largely on intuition and local custom rather than on the experience of many communities and methodically developed information. To provide local officials with a broader basis for decision-making, the Office of Solid Waste Management Programs (OSWMP) of the U.S. Environmental Protection Agency decided to develop this guide, which draws on information from 8 years of research and systems analysis in the field. It is not suggested that use of the guide will always lead to the best solutions, but it can assist in placing the issues within a decision-making framework that is based on the latest available information.

Our intention is to regularly update the guide so that it will continue to reflect the rapidly changing field of solid waste management. We welcome suggestions for improvement and other comment from readers.

While all parts of OSWMP contributed to the writing of the guide, the Systems Management Division was responsible for its planning and development. Special acknowledgment is made to Robert A. Colonna, the division director, and to Cynthia McLaren, the project officer responsible for coordinating the development of the guide.

—Arsen J. Darnay
Deputy Assistant Administrator
for Solid Waste Management

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conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation environmental effects decisions collection

Summary

conservation, environmental effects decisions collection, transport processing, disposal criteria cost institutional factors, resource conservation environment transport processing disposal

This guide presents the key issues of solid waste management in a decision-making context. It attempts to anticipate all of the important decisions which local government managers must make in the effort to develop and operate solid waste programs in a responsive, cost-effective manner. Each chapter presents an issue, describes the alternatives, gives the advantages and disadvantages, and concludes with a summary statement which may include an EPA recommendation on the issue.

CRITERIA FOR DECISION-MAKING

There are four basic categories of criteria by which decisions are made in this field: costs, environmental factors, resource conservation, and institutional factors. The key points in each of these categories are as follows:

- Costs
    - Operating and maintenance
    - Capital (initial investment)
- Environmental factors
    - Water pollution
    - Air pollution
    - Other health factors
    - Esthetic considerations
- Resource conservation
    - Energy
    - Materials
    - Land
- Institutional factors
    - Political feasibility
    - Legislative constraints
    - Administrative simplicity

These criteria determine most decisions in the solid waste field. The cost criteria are among the most important to local managers, and therefore cost information is presented for as many of the issues as possible. Environmental criteria are most important in the areas of waste storage and disposal because these functions represent prolonged exposure of wastes to the environment. Collection and processing are usually short-term operations and therefore do not cause major environmental problems.

Resource conservation is a criterion just beginning to be observed seriously by local governments as citizens become increasingly conscious of this issue.

Finally, institutional factors are sometimes the most important criteria, although not as easy to quantify or deal with as costs. Also, these criteria are less easily generalized, so each manager has to identify the institutional criteria peculiar to his locale. Nevertheless institutional factors should always be of major concern to the decision maker since they frequently prevent a decision from being made or eliminate an alternative.

DECISIONS TO BE MADE

Solid waste management is concerned largely with four major functions: collection, transport, processing, and disposal (Figure 1).

In designing a solid waste collection system, one of the first decisions to be made is where the waste will be picked up: the curb or the backyard. This is an important decision because it affects many other collection variables, including choice of storage containers, crew size, and the selection of collection equipment.

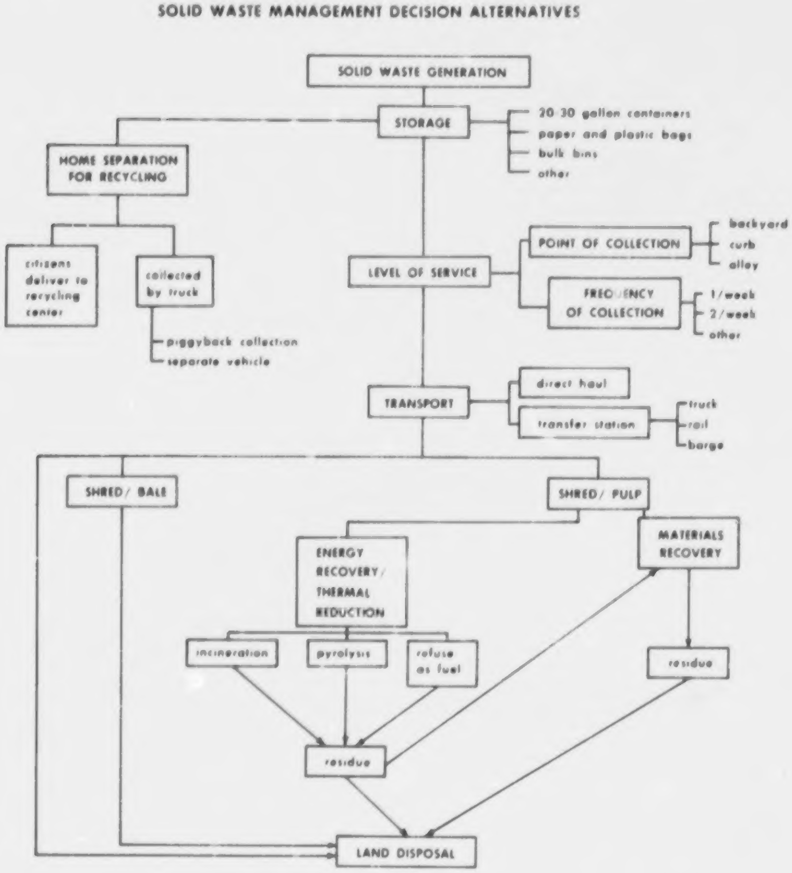
SOLID WASTE MANAGEMENT DECISION ALTERNATIVES
SOLID WASTE GENERATION
STORAGE
20-30 gallon containers
paper and plastic bags
bulk bins
other
HOME SEPARATION FOR RECYCLING
citizens deliver to recycling center
collected by truck
piggyback collection
separate vehicle
LEVEL OF SERVICE
POINT OF COLLECTION
backyard
curb
alley
FREQUENCY OF COLLECTION
1/week
2/week
other
TRANSPORT
direct haul
transfer station
truck
rail
barge
SHRED/ BALE
SHRED/ PULP
ENERGY RECOVERY/ THERMAL REDUCTION
MATERIALS RECOVERY
incineration
pyrolysis
refuse as fuel
residue
residue
LAND DISPOSAL

FIGURE 1. This flowchart illustrates the decisions which must be made from the point of generation to the ultimate disposal of residential solid waste. These decisions encompass the four major solid waste functions: collection (including storage, level of service, and the separation of materials for recycling); transport; processing (including volume reduction through shredding and/or baling and resource recovery); and ultimate disposal.

Another key decision is frequency of collection. Both point of collection and frequency of collection should be evaluated in terms of their impact on collection costs. Since collection costs generally account for 70 to 85 percent of total solid waste management costs, and labor represents 60 to 75 percent of collection costs, increases in the productivity of collection manpower can dramatically reduce overall costs.

Systems with once-a-week curbside collection help maximize labor productivity and result in significantly lower costs than systems with more frequent collection and/or backyard pickup. The main reason many communities retain twice-a-week backyard service is that the citizens demand this convenience and are willing to pay for it.

The choice of solid waste storage containers must be evaluated in terms of both environmental effects and costs. From the environmental standpoint, some storage containers can present health and safety problems to the collectors as well as to the general public. Therefore, the decision facing a community is, Which storage system is both environmentally sound and the most economical given the collection system characteristics? For example, paper and plastic bags are superior to many other containers from a health and esthetic standpoint and can increase productivity when used in conjunction with curbside collection. However, with backyard collection systems, bags have little effect on productivity.

Another factor to be considered in examining storage alternatives is home separation of various materials for recycling. The collection of newsprint for recycling is a growing practice that many cities may consider implementing in the near future. The technique of greatest interest to municipal decision-makers is separation by the generator and collection by either the regular collection truck equipped with a special bin for the paper or a separate truck.

The primary factor to consider in implementing a separate collection system is whether the benefits of paper recovery outweigh the costs involved. The economic viability of separate collection depends primarily on the local market price for the paper and the degree of participation by the citizens. If these factors are positive, it may be possible to implement a paper recovery system with no increase and possibly a savings in collection operating costs; often no additional capital expenditures are required.

The distance between the disposal site and the center of the city will determine the advisability of including a transfer station in the transport system. In addition to distance traveled to the disposal site, the time required for the transport is a key factor, especially in traffic-congested large cities.

The trade-offs involved in transfer station operations are the capital and operating costs of the transfer station as compared to the costs (mostly labor) of having route collection vehicles travel excessive distances to the disposal site. These trade-offs can be computed to find the point at which transfer becomes economically advantageous.

The sheer quantities of solid waste to be disposed of daily makes the problem of what to do with the waste, once it has been collected, among the most difficult problems confronting community officials. A crisis situation can develop very quickly, e.g., in the case of an incinerator or land disposal site forced to shut down because of failure to meet newly passed environmental regulations, or it can build gradually over a period of time if needed new facilities are not properly planned for and put into service.

There are three basic alternatives for disposal, with subalternatives for some of them (Table 1). The three major alternatives are: direct disposal of unprocessed waste in a sanitary landfill; processing of waste followed by land disposal; and processing of waste to recover resources (materials and/or energy) with subsequent disposal of the residues.

Direct haul to a sanitary landfill (with or without transfer and long haul) is usually the cheapest disposal alternative in terms of both operating and capital costs. However, it may not be the best from an environmental standpoint because of the danger of water pollution from leachate. This alternative is also wasteful of land and resources.

With the second alternative, processing prior to land disposal, the primary objective of the processing is to reduce the volume of wastes. Such volume reduction has definite advantages since it reduces hauling costs and ultimate disposal cost, both of which are, to some extent, a function of waste volume. However, the capital and operating cost to achieve this volume reduction is significant and must be balanced against the savings achieved.

An additional consideration is the environmental benefits which might be derived from the volume reduction process. In some cases, shredding and baling may reduce the chances for water pollution from leachate. This alternative is more conserving of land than sanitary landfilling of unprocessed wastes but by itself provides no opportunity for material or energy recovery.

The third category of disposal alternatives are those processes which recover energy or materials from solid waste and leave only a residue for ultimate land disposal. In terms of economics, there are significant capital and operating costs associated with all these energy and/or materials recovery systems. However, if markets are available, both energy and materials can be sold to reduce the net costs of recovery.

While resource recovery techniques may be more costly than other disposal alternatives, they do achieve the goal of resource conservation and the residuals of the processes require much less space for land disposal than unprocessed wastes.

Affecting all four major functions are basic decisions regarding how the solid waste system will be managed and operated. This includes how the system will be financed, which level of government will administer it, and whether a public agency or private firm will operate the collection, transport, processing, and disposal functions. The criteria most relevant for making these decisions are the institutional factors of political feasibility and legislative constraints.

TABLE 1

COMPARATIVE ECONOMICS AND FEASIBILITY OF MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS

Process	Comments	Feasibility	Capital costs per ton of daily capacity	Operating cost per ton		
				Total	Revenue	Net
Sanitary landfill	A fair average allowance of landfill space is 4 cu yd per capita; therefore, for a site to serve a population of 100,000 and last 20 years, an area of 310 acres is required if the waste is deposited 20 ft deep.	Institutional—there may be active citizen opposition to potential locations. Technical—depends on geological characteristics of the land. Economic—decided savings in cost per ton if facility handles over 100 tons per day.	*	$1-$4	None	$1-$4
Sanitary landfill with transfer	Requires transfer station and transport by large-body trucks, rail, or barge.	Institutional—resistance of communities on receiving end to accept "somebody else's garbage." Technical—feasible. Economic—varies with particular case.	*	Truck transfer, $2.25-$4.50 Rail haul, $7-$14	None	$2.25-$4.50 $7-$14
Conventional incineration	Obsolete—300 units in use.	Technical—feasible. Economic—cannot economically meet new air pollution standards.	$15,000-$20,000	$8-$15		$8-$15
Steam generation from waterwall incinerators	Process being demonstrated at Lowell, Mass.	Technical—1 year's operating experience at full scale in Chicago. Economic—markets for steam are limited. No steam has been sold from existing units.	$10,000-$15,000	$9-$15	$0-$6	$3-$15
Solid waste as fuel in utility or industrial boilers	Process using hammermill for size reduction is being demonstrated at St. Louis. Process is feasible. Air and water pollution factors unknown. Process using hydrapulper for size reduction at Franklin, Ohio, produces a material that, when moisture content is reduced, appears to make an excellent fuel, but has not been tested on a full scale. Cost data not available. Ferrous metal recovery being demonstrated with both processes.	Institutional—owner/operator must contract with utility for sale of electricity. Technical—combustion in utility boiler as supplement to coal has been demonstrated. Economic—practical feasibility depends on cooperation of local utility or user industry.	$7,000-$12,000	$10-$14	$5	$5-$9
Pyrolysis: Solid waste converted into combustible gas and oil	Three processes demonstrated at 200 tons per day or larger. Two other processes still in pilot stage.	Technical—process involves high temperature chemical breakdown (rearrangement of carbon molecules) of organic refuse. Economic—transportability and quality are important factors. Storability and transportability offer broad market application. Pyrolysis systems offer high long-term potential.	$10,000-$18,000	$10.00-$13.50	$5	$5.00-$8.50
Heat recovery	1,000 tons per day prototype plant is being built at Baltimore using the Monsanto Landgard system to generate steam. Other processes are in lesser stages of development.	Technical—risk is minimized because the Monsanto process utilizes a more conventional technology.	$14,000-$18,000	$9.50-$12.50	$4-$5	$4.50-$8.50

(Continued)

TABLE 1

COMPARATIVE ECONOMICS AND FEASIBILITY OF MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS—*Concluded*

Process	Comments	Feasibility	Capital costs per ton of daily capacity	Operating cost per ton		
				Total	Revenue	Net
Composting	Most environmentally sound recovery process. Because markets for compost have been below expectations, all but one U.S. compost plant has closed.	Technical—technology has been proven. Economic—inadequate markets for compost have precluded success.	*	*	*	*
Materials recovery: Recovery of minerals from incinerator residue	Process being demonstrated at Lowell, Mass. Projected economics of $.75-$3.75 profit per ton of residue. Based on Bureau of Mines process.	Technical—process not yet demonstrated at full scale.	$4,000	*	*	*
Newsprint, corrugated, and mixed office papers	Separate collection of these materials provides supply that can command prices between $20 and $80 per ton.	Technical—separate collection, possibly with baling, is required. Economic—recovery can be profitable. Markets for paper are improving due to fiber shortage.	*	*	*	*
Mixed paper fibers	Mechanical separation of fibers demonstrated at 150 tons per day at Franklin, Ohio. Fibers being sold to roofing felt manufacturer for $25 per ton.	Technical—technology has been demonstrated at full scale. Economic—fiber quality from Franklin plant is low, suitable only for construction uses. Quality can be upgraded by further processing.	*	*	*	*
Glass and aluminum	Many pilot and development efforts underway. Franklin, Ohio, demonstration furthest developed—operation began August 1973.	Technical—technology being developed. Economics—market potential is adequate but system economics uncertain as yet.	*	*	*	*

* Not available.

Financing is needed for operating costs and capital costs. For generating operating revenues, there are two techniques: tax levies from the city's general fund or assessment of a direct charge on the users of the system. A direct charge may be fixed or vary according to the level of service rendered. The issue of political feasibility becomes relevant when a change from tax financing to a user charge is being considered. There is often citizen opposition to receiving a bill for a service which was previously provided "for free" (hidden in the property tax).

For capital expenditures, municipalities have basically two alternatives: borrowing and current revenues. The decision of which method will be used is affected by factors such as the financial status of the city, citizen attitudes, legislative constraints on debt limits or long-term contracts, and the size of the project to be undertaken.

The ownership and operation of residential collection systems ranges from completely public collection to collection by private contractors in open competition. One common pattern is the collection of residential waste within the city limits by a municipal system under the public works department and collection of adjoining suburban areas by private contractors. In other communities, collection is divided between the public and private sectors with private contractors operating under exclusive franchises with the city. These are just two of the many patterns of ownership and operation of the collection function which exist within the country today. The ownership and operation of disposal functions are also under public and private auspices and combinations of both.

The following pages (Tables 2–11) present a brief overview of major issues and the alternatives available in dealing with them, plus the advantages and disadvantages of each alternative and the conditions which favor one alternative over another. These and related issues are presented in detail in the chapters of this guide.

TABLE 2

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF RESIDENTIAL WASTE STORAGE CONTAINERS, AND CONDITIONS THAT FAVOR THE USE OF EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Paper or plastic bags	Easier to handle—no lids to be removed or replaced Less weight to lift Reduces spillage and blowing litter when loaded in truck One-way container—no cans left at curb Eliminates odors and necessity to clean dirty cans Prevents fly entrance Increases speed and efficiency of collection Reduces contact of collector with waste	Cost per bag Bags can fail if filled too full or if too thin Susceptible to animal attacks Not suitable for bulky, heavy, or sharp objects May be difficult to obtain due to energy crisis	Curbside collection
Metal or plastic cans (20- to 30-gal)	Reasonable size for collector to lift Economical	Must be cleaned regularly when not used with liners	Backyard collection
Containers for mechanized collection	More efficient than manual collection	Residents oppose storage of other people's waste on their property	Alley space available for storage
Drums (55-gal)	None	Lower collection efficiency Excessive weight can result in back injury and muscle strain Difficult to handle Lack of lids allows insects to breed in waste and odors to escape Rust holes at bottom of drum allow rodents to feed on waste	Unacceptable alternative
Stationary storage bins	None	Inefficient—must be emptied manually Lack of proper cover leads to insect and rodent infestation Necessity for hand shoveling of wastes poses health hazard to collectors	Unacceptable alternative

Table 3

POTENTIAL ADVANTAGES AND DISADVANTAGES OF CURBSIDE/ALLEY AND BACKYARD COLLECTION, AND CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Curbside/ alley	More efficient Less expensive Requires less labor Facilitates use of paper or plastic bags Reduces collector injuries	Cans at curb look messy Special arrangements must be made for handicapped and elderly Residents must remember day of collection	High collection costs Unwillingness on part of residents to pay higher taxes or user charge
Backyard	No effort required by residents No mess at curbs	More expensive High labor turnover Increases number of collector injuries	Quality of service provided more important criterion than economics

Table 4

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT FREQUENCIES OF COLLECTION, AND CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Once per week	Less expensive Requires less fuel	Improperly stored waste can create odor and fly problems	Adequate storage provisions Cold to moderate climate
Twice per week	Reduces litter in urban areas Reduces storage volume requirements	More expensive Requires more fuel	Quality of service provided more important criterion than economics Warm climate
More than twice per week	Reduces litter in urban areas Reduces storage volume requirements	More expensive Requires more fuel	Seriously restricted storage space Dense population

Table 5

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOURCE SEPARATION OF SOLID WASTE, AND THE CONDITIONS THAT FAVOR IT

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
All alternatives: Separate collection Piggyback collection Recycling centers	Simple to implement Reduces solid waste volume at sanitary landfill	Requires citizen cooperation Requires market for separated waste materials Results in separation of only a small portion of the total waste stream Scavengers may take material for private gain	Markets exist for the materials recovered Citizen support of resource recovery is high

TABLE 6

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIRECT HAUL TO DISPOSAL SITES AND USE OF TRANSFER STATIONS, AND THE CONDITIONS THAT FAVOR EACH METHOD

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Direct haul by collection trucks to disposal site	Requires no capital expenditure	Changes in disposal site location require rerouting of all collection trucks	Close-in disposal sites available Low labor rates Nonurban area
Transfer station	Cuts down on nonproductive collection time Total system cost can be reduced In-town location where residents can bring their waste Makes collection operation independent of the actual disposal site Facilitates the addition of resource recovery or volume reduction equipment at the transfer site Proven technology Permits land reclamation (e.g., filling in strip mines) at location distant from generation point	Nonproductive time spent in transport increases costs Requires extra materials handling step Requires capital expenditures for land, structures, and equipment To achieve savings in existing system, a reduction in the number of crews is needed Difficult to find recipient of waste outside of immediate political jurisdiction There is usually citizen opposition to proposed transfer sites if located near residential areas	High labor costs Distant disposal site Large collection crews Shortage of land for sanitary landfills at reasonable price Urban areas

TABLE 7

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS, AND THE CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Sanitary landfilling of unprocessed solid waste	Simple, easy to manage Initial investment and operating costs are low Can be put into operation in short period of time May be used to reclaim land Can receive most types of solid waste, eliminating the necessity for separation of wastes	Proper sanitary landfill standards must be observed or the operation may degenerate into an open dump Difficult to locate new sites because of citizen opposition Leachate may create water pollution Production of methane gas can constitute a fire or explosion hazard Obtaining adequate cover material may be difficult Process excludes resource conservation	Adequate land, close to source of waste, is available at reasonable price
Sanitary landfilling of baled solid wastes	Extends life of landfill (double that of unprocessed wastes) Lowers operating costs at the disposal site Reduces hauling costs where distant sites are used Permits immediate use of landfill site for other purpose upon completion (minimal settling)		Long hauls needed to reach landfill sites Shortage of landfill sites require maximum utilization of available land Use of site is desired immediately after completion

(Continued)

TABLE 7

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
	May reduce chance of water pollution from leachate		
Sanitary landfilling of shredded solid waste	Does not require daily cover under some conditions More easily placed and compacted Extends life of landfill Initial investment and operating costs are relatively low Vehicles do not become mired in waste in inclement weather Reduces problems with vectors Does not support combustion or lead to blowing litter Shredding at landfills may be first step in implementing a resource recovery system	Jamming and bridging of the feeding equipment can reduce throughput of the mill High level of component wear, especially on hammer Danger to employees from flying objects, explosions within the mills, and noise Leachate may create water pollution	Cover material is difficult to obtain Shortage of landfill sites requires maximum utilization of available land
Materials recovery	Reduces volume of land required for solid waste disposal High public acceptance Lower disposal costs through sale of recovered materials and smaller quantity of solid waste to dispose of in sanitary landfill	Technology for some operations still new, not fully proven Requires markets for recovered materials High initial investment required for some techniques Materials must meet specifications of purchaser Sanitary landfill is still needed for disposal of residues	Markets for sufficient quantities of the reclaimed materials are located nearby Land available for sanitary landfilling is at a premium Heavily populated area to insure a large steady volume of solid waste to achieve economies of scale
Energy recovery systems	Landfill requirements can be reduced Finding a site for an energy recovery plant may be easier than finding a site for a landfill or conventional incinerator Total pollution is reduced when compared to a system that includes incineration for solid waste disposal and burning fossil fuels for energy More economical than environmentally sound conventional incineration or remote sanitary landfilling High public acceptance	Requires markets for energy produced Most systems will not accept all types of wastes Specific needs of the energy market may dictate parameters of the system design Complex process requiring sophisticated management Needs relatively long period for planning and construction between approval of funding and full-capacity operation Sanitary landfill still required for residues Technology for some operations still new, not fully proven	Heavily populated area to ensure a large, steady volume of solid waste to take advantage of economy of scale Availability of a steady consumer for generated energy to provide revenue Desire or need for additional low-sulfur fuel source Land available for sanitary landfilling is at a premium

TABLE 8

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
General obligation bonds	One of the most flexible and least costly public borrowing method Requires no technical or economic analysis of particular projects to be funded Small projects may be grouped to obtain capital Least difficult to market	Requires voter approval and elections may be expensive Must not exceed municipality's debt limit Issuing jurisdiction must have power to levy ad valorem property tax Transaction costs impose a benchmark minimum of $500,000 Capital raised becomes part of general city treasury, thus other city expenditures could draw on amount, unless specifically earmarked for solid waste Since careful project evaluation is not required, decisionmakers may be unaware of technological and economic risks Ease of raising capital is a deterrent to change in existing public/private management mix, little incentive for officials to consider use of private system operators	Size of community is small or medium Voter approval likely
Municipal revenue bonds	Projected revenues guarantee payment Can be used by institutions lacking taxing power, such as regional authorities and nonprofit corporations Does not require voter approval Is not constrained by municipality's debt limitations	Effective minimum issue of $1 million, thus only useful for capital-intensive projects Information requirements of the bond circular are extensive Technical and economic analysis of project must be performed by experts outside the municipal government	Capital-intensive projects Regional facilities desired Municipality's debt limit has been reached Initiating institutions lack taxing power

(Continued)

TABLE 8

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH—*Continued*

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
		Cost is higher than general obligation bonds Can be used only for specific projects	
Bank loans	Small-scale capital requirements for short-term funding (5 years or less) Some medium-term funding applicability since notes may be refinanced as they expire Relatively low interest cost because interest paid by municipality is tax-free to bank Source of funds on short notice No external technical or economic analysis required Essentially no minimum Relatively inexpensive Voter approval generally not required No debt ceilings Can be used by institutions lacking taxing power	Low maximum Short term Not useful for capital-intensive projects	Capital requirement is small Funds needed on short notice
Leasing	Useful as interim financing for equipment needed before appropriations or long-term capital arrangements can be made Negotiating agreement is simple and fast Only certification required is assurance of municipality's credit standing	Relatively high annual interest rate (9–18 percent) Amount of capital is usually limited Lease terms are generally 5 years or less Some States prohibit municipalities from entering multiyear, noncancellable contracts	Equipment needed before appropriations available Municipality has good credit rating

(Continued)

TABLE 8

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
	Reduces demand on municipal capital outlays since original capital raised by private corporation	City will not own asset unless it purchases facility upon completion of lease period	
Leveraged leasing	Reduces demand on municipal capital funds Interest rate on entire financial package may be lower than general obligation bonds	Legally complex City will not own asset unless it purchases facility upon completion of leasing period	
Current revenue capital financing	Least complex mechanism available No consultant or legal advice required No need for formal financial documents	No cost in the conventional sense (but higher taxes result) Communities' ability to raise capital is frequently lacking Current taxpayers should not have to pay for a system that will be used far into the future Solid waste projects must compete with other municipal demands	Amount of capital necessary is small Voter approval dependable
Private financing	Municipality not involved in external consulting Municipality need not borrow capital	Municipality must locate acceptable firm and negotiate contract Higher cost of capital reflected in system charges May be legal constraints preventing signing of long-term contract Displacement of city employees	

TABLE 9

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TAXES AND USER CHARGES AS SOURCES OF OPERATING REVENUES, AND THE CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Tax-financing	Simple to administer—no separate billing and collection system necessary If part of local property tax, it is deductible from Federal and State income taxes	Solid waste management is often a low-priority item in the budget and receives inadequate funds Costs are hidden—less incentive for efficient operation	Tradition of tax-financing for most public services
User charges	Enables localities to balance the cost of providing solid waste services with revenues Citizens are aware of costs of service and can provide an impetus for more efficient operations	More complex to administer Can cause problems for users on fixed incomes	Ceiling on property tax rates

TABLE 10

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF PUBLIC AND PRIVATE OPERATION OF COLLECTION SERVICES, AND THE CONDITIONS THAT FAVOR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public:			
Municipal department	Tax-free Nonprofit Economies of scale Can institute separate collection for recycling Can institute mandatory collection City has administrative control	Monopolistic Lack of incentive to maximize efficiency Financing and operations often influenced by political constraints Frequently financed from general tax fund and subject to 1-year budgeting process Solid waste management often low-priority item in budget Labor pressures may result in inefficient labor practices and strikes Poor equipment replacement policies Policies of job-support inflate labor costs	Past history of unsatisfactory contractual operations for public services Public predisposition towards government operation of public services Quality of service provided more important criterion than economics

(Continued)

TABLE 10

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF PUBLIC AND PRIVATE OPERATION OF COLLECTION SERVICES, AND THE CONDITIONS THAT FAVOR EACH—*Continued*

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public corporation or utility (usually serving a multijurisdictional or regional area)	Tax-free Nonprofit Economies of scale Self-financing Multiple-year budgeting Operated independently of political structure Can institute separate collection for recycling Can institute mandatory collection	Monopolistic Labor pressures may result in inefficient labor practices and strikes	History of regional cooperation Rural or semi-rural area Area with rising costs
Private:			
Open competition	Competition may reduce costs Self-financing	Danger of collusion among haulers to reduce competition and keep prices high Cutthroat competition can result in business failures and service interruptions Overlapping routes, waste of fuel Cannot institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative
Controlled entry through use of permit system	Competition may reduce costs Self-financing	Subject to political abuse in the awarding of permits Creates oligopoly Overlapping routes, waste of fuel Can't institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative
Exclusive franchise via contract with local government	Competitive bidding for contract(s) helps keep prices down Can institute separate collection for recycling	Danger of collusion in bidding	Flexibility is needed to make changes in operations that would result in labor savings and other cost reductions

(Continued)

TABLE 10

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF PUBLIC AND PRIVATE OPERATION OF COLLECTION SERVICES, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
	Can institute mandatory collection City has administrative control		Existence of qualified private contractors Public predisposition towards private sector involvement in public services Newly incorporated communities, or where population growth is outpacing ability of community to provide public services
Combination of public and private:			
Municipal system and private firms under contract	Competition helps keep prices down Alternative available if either sector cannot deliver service because of strikes, for example Can institute separate collection for recycling Can institute mandatory collection City has administrative control		Municipality is expanding through annexation or merger with other jurisdictions Changing from separate garbage and trash collection to combined collection
Competition between municipal system and private firms	Competition helps keep prices down	Overlapping routes, waste of fuel Can't institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative

TABLE 11

POTENTIAL ADVANTAGES AND DISADVANTAGES OF PUBLIC AND PRIVATE OPERATION OF DISPOSAL FACILITIES, AND THE CONDITIONS THAT FAVOR EACH TYPE OF OPERATION

Alternatives	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public	Tax-free Nonprofit Can obtain low-interest rates and/or government grants for capital-intensive systems	Community may not have expertise to operate sophisticated disposal facility	Public predisposition towards government operation of public services
Private	Local government does not need to raise capital Often easier for private firms to buy land for a disposal site	Community may have no control of prices if only privately operated disposal site is available Operator may base decisions on basis of financial reward rather than community needs Legal constraints may prevent signing of long-term contract Displacement of city employees Municipality must locate acceptable firm and negotiate contract	Borrowing power of community and/or voter approvals for bond issues needed for capital improvements in disposal facilities are limited or not available Flexibility is needed to make changes in operations that would result in labor savings and other cost reductions Desire of local government to avoid administrative details in operation of disposal facilities Community lacks sufficient technical and management expertise for efficient operation of the type of advanced disposal system it would like to install Territorial flexibility is needed to permit operation across political boundaries, where appropriate regional agencies do not exist

criteria: cost, institutional factors, resource conservation, environmental effects

decisions: collection, transport, processing, disposal

INSTITUTIONAL AND ORGANIZATIONAL APPROACHES

criteria: cost, institutional factors, resource conservation, environmental effects

decisions: collection, transport, processing, disposal

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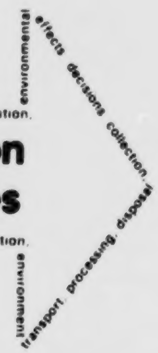
conservation, environmental effects decisions: collection, transport, processing, disposal criteria: cost, institutional factors, resource conservation.

Public and Private Operation of Residential Collection Services

conservation, environmental effects decisions: collection, transport, processing, disposal criteria: cost, institutional factors, resource conservation.


environmental
effects decisions collection,
transport, processing, disposal
environment

In contrast to many other public services, residential solid waste collection is often under mixed public and private auspices rather than being exclusively a government service. A key decision in solid waste management is, "Who should collect the waste?"

ALTERNATIVES

The following examples describe the range of answers available to the above question:

- Public (municipal) collection, usually under a governmental department such as the department of public works.
- Public corporation, authority, or utility which usually serves a multijurisdictional or regional area and is financially self-supporting and administered separately from other agencies of city government.
- Private firms operating under exclusive franchises by which each is licensed to operate alone in a given area. A franchise may or may not be awarded on the basis of competitive bidding, and may or may not include a contract regulating prices and limiting the time period of the franchise.
- Private firms operating under permits which limit the number of firms which can operate in a given geographical area. The governmental agency that issues the permits may also regulate prices, but the contractor must compete for customers within the permit area.
- Private firms in open competition with no regulations limiting the number of firms operating in a given area.

In addition to these alternatives, various combinations of public and private systems may exist in some communities. Examples of such combinations include situations where a municipally operated system collects a portion of the residences and private contractors with franchises collect the remaining stops. In other communities the municipal system may compete with the private sector for customers.

ADVANTAGES AND DISADVANTAGES

Public (Municipal) Operations

Ownership and operation of the collection service by the local government is a common practice. The advantages of this alternative include the nonprofit, tax-exempt status of public operations which, compared with private operation, should result in reduced costs. In addition to potential cost savings, administrative control of the collection system by a public agency is often necessary for the implementation of collection policies which require systemwide compliance to be effective. Examples of such policies include mandatory collection requirements and the implementation of separate collection of newsprint and other materials for resource recovery.

The disadvantages of public ownership and operation of the collection system include the monopolistic nature of such operations which can result in a lack of stimulus towards efficiency. Another disadvantage is the potential for political interference in the operations and financing of the system.

In establishing labor policies such as crew size and daily work tasks, administrators of public systems may be constrained by labor union pressures and stated or unstated policies of job support. Labor pressures for higher pay, less work, and greater job security limit the flexibility of many public systems to implement labor-saving techniques.

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Also, labor strikes causing discontinuities in service are more prevalent in the public sector than in private collection firms.

In the area of financing, the solid waste system may be particularly affected as a result of the low priority given solid waste management in many city budgets. This situation can inhibit innovation and reduce efficiency due to inadequate equipment replacement policies.

Public Corporation (Utility)

This alternative shares many of the advantages of municipally operated solid waste systems, including nonprofit, tax-exempt status and centralized administrative control of collection policies. The public corporation has the additional advantage of operating independently of the political structure as a self-financing, businesslike entity.

The disadvantage of a public corporation is that it is a monopoly, and unless performance and rates are carefully monitored by a body separate from the operating utility, the monopoly is uncontrolled.

Private Firms with Exclusive Franchises

The potential advantage of having private contractors perform solid waste collection is that the competition between various private firms should keep costs down. In the situation where franchises are awarded under a competitive bidding system, the community can retain control of collection policies and derive the efficiencies of a competitive, profit-motivated collection system.

The disadvantage of this alternative centers upon the need for active regulation of the franchise by a public agency. Exclusive franchises should be awarded on a bid basis with contract specifications featuring positive incentives for contractor firms to maintain and improve efficiency. The absence of these controls may result in excessive collection costs.

Private Firms with Restricted Entry

The purpose in limiting the number of contractors that operate in a given area is to counteract the negative aspects of excessive competition (business failures, discontinuities in service), while at the same time maintaining a competitive atmosphere. However, such a system is subject to political abuse in the awarding of permits and often creates a semimonopolistic situation for the private contractors.

In addition, having several contractors operating in the same area leads to overlapping routes and inefficient use of fuel.

Private Firms in Open Competition

While competition may keep prices low, a situation with no administrative control over solid waste collection can degenerate into cutthroat competition and severe price cutting, leading to a high rate of business failure and interruptions in service. There is also the danger that the contractors will informally agree to honor each other's territories, thus removing the competitive element and resulting in higher prices. This alternative, like the previous one, results in the duplication of resources and inefficient use of fuel.

OTHER CONSIDERATIONS

If a community's present collection system is unsatisfactory, a change in the institutional organization of the system may be one means of alleviating the problems. The risks in such a change include high initial costs involved in instituting a new organizational structure and the possibility of dramatic social and economic impacts in terms of losses or gains in the number of jobs. Without redesign or reorganization, however, it may be very difficult to change inefficient practices, traditions, and policies, bring in better management, or increase reliability and productivity of the labor force. Thus the only alternative may be institutional change.

The alternative chosen by a particular community depends on many conditions. Some community situations suggest the preferability of public operation while others suggest private operation as being more appropriate.

Conditions favoring public ownership and operation would include:

- Public predisposition toward government operation of public services
- Quality of service provided is more important criterion than economics
- Past history of unsatisfactory contractual operations for public service

Conditions favoring private ownership and operation would include:

- Public predisposition toward private sector involvement in public services
- Flexibility is needed to make shifts in operation which would produce labor savings and other cost reductions
- Desire of local government to avoid administrative details in operation of collection system
- Population growth is outpacing ability of community to provide public services
- Existence of qualified private contractors

If a community plans to contract with a private solid waste firm for collection service, it becomes the job of the local government to administer the bidding process and to monitor and enforce the terms of the contract.

The tools of enforcement consist of the government's ability to withhold payments and ultimately cancel the contract if the firm does not meet minimum performance standards. Besides these drastic measures, positive incentives in the contract for firms to maintain and improve efficiency can have a major effect on their performance. The design of the contract specifications is a crucial factor in assuring that a reputable collection firm is chosen in the bidding process.

The contract specifications must be sufficiently general to attract a reasonable number of bidders but at the same time restrictive enough to discourage bidding by incompetent or disreputable collection firms. A large number of bidders is important to minimize possible collusion in the bidding process. If there are very few bidders for the contract areas, there is always the potential that competitors will fix their bids so everyone gets a share.

One way to encourage a larger number of bids is to allow sufficient time between awarding of the contract and start of the contract period so that small firms can obtain the additional resources that may be required should they have the winning bid.

To discourage bidding by disreputable firms, governments frequently require a performance bond from each prospective bidder. Such a bond makes the issuing financial institution liable, up to the amount of the face value of the bond, in the event that the bonded contractor fails to abide by the terms of the contract.

Other key issues to be considered in contracting with private firms for solid waste collection are: the number of subareas into which a given jurisdiction should be divided; whether or not contracts on all areas should be let simultaneously or staggered over time; the maximum number of subareas any one contractor should be allowed to service; and the length of time between successive bidding opportunities.

The greater the number of subareas into which the jurisdiction is divided, the greater the number of contractors the jurisdiction can support, and the greater the number of contractors who must be available for bidding. However, care must be taken so that each subarea is in fact large enough to support a collector. In addition, it is desirable to stagger the bidding for the various subareas so that the competition for each is more intense.

The number of simultaneous contracts one firm can hold should be restricted to maintain an adequate number of bidders in the area. If one firm holds a large number of franchises, the total number of collection firms the area will support is reduced, and there will be a smaller number of available bidders. However, the limit on the number of contracts one firm can hold should not be too severe, or the competitive spirit will be diminished among the firms holding current contracts. The length of the contract period can also affect the success of the bidding process. A contract period that is too long can reduce the contractor's incentive to maintain high quality service, but the contract should be long enough to allow amortization of the collection equipment. EPA recommends a contract period of 3 to 5 years.

Another problem that must be anticipated in granting franchises to private contractors is the possibility of requests for midterm rate adjustments of a contract. The need to adjust a contract may arise from underbidding by the contractor, either deliberately or through inaccurate calculations or unforeseen circumstances, such as severe inflation or changes in collection procedures. If such midterm adjustments are relatively easy to obtain, there will be little incentive for accurate bidding and efficient operation over the life of the contract. For this reason, any procedure for permitting midterm adjustments should be very stringently followed.

To aid cities in designing a contract, EPA and the National Solid Waste Management Association (NSWMA) have developed a model contract. A copy of this contract can be obtained from the NSWMA.

A final control over private contractors with exclusive franchises is complaints. A responsive complaint procedure that includes inspection and followup must be an integral part of administering a contract system.

CONCLUSIONS

Regardless of whether the public or private sector performs the residential solid waste collection function, the local government should retain administrative control over this function. The alternatives among institutional arrangements which satisfy this condition are municipal operations, public corporations, and private firms under contract to the municipality. It is possible to achieve a high level of productivity with any one of these institutional arrangements, but past experience tends to indicate that the private sector, as a whole, is more productive than the public sector due to the profit motive involved. Higher productivity should result in lower collection costs, but this is likely to happen only if the private sector operates under contracts which encourage competition and protect against excessive profits.

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conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

Multijurisdictional Approaches

conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

Each year environmental regulations affecting the management of solid waste grow more stringent, while the quantity of waste increases along with capital and operating costs. Many communities are looking toward regional approaches to solid waste management in order to accomplish together what they cannot attain alone. The task facing local governments is to determine the conditions under which a multijurisdictional approach is best for them.

ALTERNATIVES

Several types of regional organizations that have been created for financing and management of solid waste systems are: (1) public authorities, (2) nonprofit public corporations, (3) multicommunity cooperatives, and (4) special districts. There is considerable variation among existing organizations in each of these categories as a result of differing local and State laws and specific needs and peculiarities of the participants.

Authorities

An authority is a corporate body authorized by legislative action to function outside of the regular structure of government in order to finance and construct, and usually operate, revenue-producing public enterprises.

Most municipalities or groups of municipalities establish an authority to provide a revenue-generating service when confronted with one or more of the following problems:

- The constitutional debt ceiling prohibits financing by the municipality.
- Gaining voter approval for financing is either too time consuming or too risky.
- Political activity related to the service has hampered previous programs.
- Multiple political entities will be served by the authority.
- Greater autonomy and freedom from municipal budgetary and administrative control will mean more efficient delivery of service.

The authority is well suited for financing and managing solid waste services. It can raise capital dollars from short- and long-term notes and from revenue bonds. It cannot, in most States, raise capital or operating dollars from taxes. The authority normally has no power to tax and cannot rely on the tax base of a given political jurisdiction unless officials of that jurisdiction allocate funds. Therefore, the operating funds and a portion of the capital funds are raised by levying charges on the users of the authority's service; the charges should generate sufficient income so that the service is self-supporting.

Financing through an authority is administratively complex because the authority must be designed and approved by another governmental body. The ability of the authority to raise capital depends on the debt provisions of its charter. Its ability to raise capital will also depend on the performance of its management in day-to-day operation and in meeting all the authority's financial obligations. The cost of capital to an authority will depend on what type of debt issue is used, plus how well the authority has performed. Capital financing is tax exempt.

Although there are potential advantages to establishment of an authority, there is a danger that it can become remote from government or public control. Separated from the municipal bureaucracy, protected by a board of directors, the authority can and, in some cases, does become self-serving.

Nonprofit Public Corporations

The nonprofit public corporation is similar in many respects to the authority as a means of financing and managing a solid waste system. Using this form of corporate body, the city can shift its financing requirements to an organization outside the immediate municipal bureaucracy.

The major reasons for a community to create a nonprofit corporation to perform solid waste services are ease of administrative and legal approval and the presence of a long-term commercial interest in the service.

The nonprofit corporation can be established by a city or by a group of private individuals. The important feature is that the organization is tax exempt and can issue tax-exempt bonds. To gain tax-exempt status, the corporation must satisfy the following Internal Revenue Service criteria:

- The city council must approve the project and accept the assets after bonds are paid.
- The corporation must agree to give its assets to the city after bonds are paid.
- The city must provide all easements to the corporation at no cost.
- The directors of the corporation must be city or State officials.
- The corporation must provide a public service.

A municipality has more control over a nonprofit public corporation than it does over a profit-making firm. The nonprofit corporation does not pay real estate or Federal taxes, and its capital financing can be offered as tax exempt.

The ability of the nonprofit corporation to raise capital depends on its ability to secure contracts for its services and its performance of the service, as well as any provisions in its charter which limit the type of debt or the amount of debt. The cost of capital to a nonprofit corporation will depend on the type of debt issued and the performance of the corporation. In theory the cost of capital to the nonprofit corporation should reflect the degree of risk perceived in realizing revenues because it will not have the security of the full faith and credit of a community behind it. Hence there is incentive to make investments that are quite certain to work technically and to insure that services are covered, at least to the break-even point, by contracts.

Multicommunity Cooperatives

The multicommunity cooperative is a system developed by one community to provide service to itself and several other communities. The purpose behind a multicommunity cooperative is to achieve economies of scale through better utilization of capital. It enables member communities to provide services not otherwise financially possible.

The concept offers several attractive features. It centralizes waste processing and disposal, reduces the number of small, inefficient, environmentally unsound systems operating in the area, and offers options in solid waste handling not otherwise available to member communities. Urban communities with no landfill area and with limited opportunities for incineration would benefit from a regional arrangement where the options are broader. This approach enables one political jurisdiction to take the lead, while contractually bound supporting communities indicate to the financial community that the service will be used and sufficient revenues generated.

Evaluation of the multicommunity approach as a financing mechanism is really an analysis of the community which will issue the debt in behalf of the other communities. Although each city council must approve the concept and the working agreements, the ability to raise capital will depend on the lead community's debt capacity and financial strength, which may be strained by the extra load. Tax-exempt status is available for financing of multicommunity cooperatives.

The multicommunity approach obviously depends largely on the willingness of independent communities to work together and, in particular, to let one community take a dominant role. The process of organizing the communities for cooperative action is time consuming. Where the problems can be surmounted, however, the multicommunity approach should encourage more efficient, better quality systems.

Special Districts

A "special district" is an agency of government which operates outside the regular structure of government to perform usually a single function and which relies for financial support primarily on special tax levies. Its creation requires the cooperation of the State and the political entities already existing within the region. To implement a successful program, the special-purpose district must continue to be responsive to local needs and to cooperate with local jurisdictions.

In some instances, special-purpose governments must be used because of State restrictions or because no other governmental unit can be used. The special district has an advantage over the public authority in that the district has a distinct constituency of residents, not merely a group of bondholders living in widely scattered places.

If a special district is used for providing solid waste services, the overall planning function of the general-purpose governments can be protected by having elected county officials with responsibility for solid waste management serve as the governing body of the new unit of government.

Other Techniques of Intergovernmental Cooperation

Governmental agreements can be made on a formal or informal basis. A county can, for example, make a formal agreement with one or many cities within its boundaries to perform a certain service for a predetermined fee.

Informal agreements between local governments are frequently made but are not advisable since they can lead to misunderstanding. Any initial agreement should be put down in writing in adequate detail to avoid later disagreement.

Agreements and contracts are without a doubt the most widely used formal method of cooperation among governments in the United States. They constitute a flexible yet predictable and enforceable approach. They can be used to accommodate special program needs without affecting basic structure and organization. Consequently, needed services can be provided and necessary projects undertaken without waiting for major decisions on governmental reorganization which ultimately may be necessary. The ideal organizational pattern may well be politically unfeasible.

A transfer of function occurs when one level of government is delegated responsibility for a function that another level of government or jurisdiction had. For example, in Broome County, New York, most of the cities and towns have agreed to transfer the function of solid waste disposal to the county. Similarly, Montgomery County, Pennsylvania, gained responsibility for solid waste management in all parts of the county because the increase in its population caused it to be reclassified under the State's system.

ADVANTAGES AND DISADVANTAGES

Authorities

Advantages:

- Ability to finance without regard to local debt ceiling
- Voter approval not required
- Service cannot be hampered by local political activity because board members are usually private citizens
- Can serve multiple political entities
- Autonomy and freedom from municipal budgetary and administrative control means more efficient delivery of service
- Can generate sufficient income to make service self-supporting
- Capital financing is tax exempt

Disadvantages:

- Financing is administratively complex
- Can become remote from government or public control, thus may become self-serving

Nonprofit Public Corporations

Advantages:

- Financing outside government debt limits
- Voter approval not required
- Can serve multiple political entities
- Corporation gives assets to cities after bonds are paid
- No real estate or Federal taxes, and capital financing is tax exempt

Disadvantages:

- Political influence may be exerted and flexibility lost because board members are city and State officials
- Difficult to dismantle even if better service becomes available
- Does not have full faith and credit of communities behind it

Multicommunity Cooperatives

Advantages:

- Achieves economies of scale because of better utilization of capital
- Enables member communities to provide service not otherwise financially possible
- Encourages more efficient, better quality systems

Disadvantages:

- Member communities lose some control over locations of waste disposal sites
- Loss of control over charges for use of system
- Increased interest costs when leading community is less creditworthy than other members
- Loss of autonomy
- Leader community could be hurt financially unless proper contractual arrangements are made with member communities

Special Districts

Advantages:

- The district has a distinct constituency of residents, not merely a group of bondholders living in scattered places
- Governments can be protected by having elected county officials serve as governing body of district

Disadvantages

- Must rely on special tax levies requiring voter approval
- Creates an additional governmental entity removed from the electorate and thus less responsive to citizens than directly elected entities

Governmental Agreements

Advantages:

- Contracts present a flexible, predictable, and enforceable method of cooperation
- Do not affect basic structure and organization
- Since no reorganization is required, much time is saved

Disadvantages:

- Contracts must be written in adequate detail to avoid later disagreement

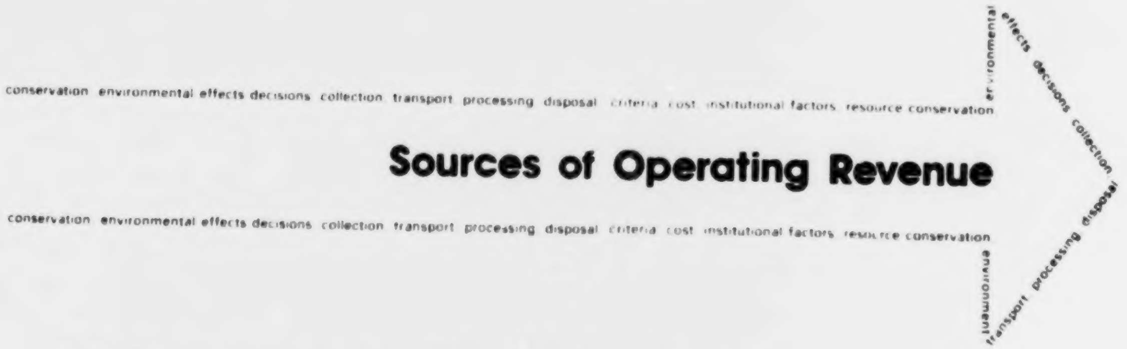
OTHER CONSIDERATIONS

Control of a multijurisdictional disposal operation should be such that collection system users have a voice in decisions affecting them, including the location of offload points, the condition of access roads, hours of operation, and restrictions on items received.

On the other hand, disposal operations can be run more efficiently if disposal managers have some control over the timing and amounts of solid waste received. Facilities can then be run at efficient levels of input, and waiting lines for offloading vehicles can be minimized.

CONCLUSIONS

Multijurisdictional approaches can be used to hire better management, spread unit costs over a larger population base, thereby taking advantage of economies of scale, and avoid costly duplication of services. Therefore, such approaches are to be encouraged wherever possible.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Sources of Operating Revenue

Traditionally, municipally operated solid waste systems have been funded with tax revenues. But with increasing pressures on municipal budget allocations, there has been a recent trend toward generating revenues through user charges. As the cost of solid waste collection and disposal rises, many communities will be examining the methods by which they generate revenues for this service.

ALTERNATIVES

There are two basic methods of generating revenues for the day-to-day operation of a solid waste system. The first method is to finance the system through taxes, either through budgetary allocation from the general tax fund or the levy of a specific tax.

The second method is to allocate the total cost of providing solid waste service among the users of the service. The charge may be either a straight or progressive user charge.

A straight user charge allocates an equal share of the costs to all users within a service level group. A user receiving backyard collection may pay more than a user receiving curbside service, but all backyard users are charged the same, regardless of the amount of waste they generate. This type of user charge can be collected by adding a separate solid waste charge to a periodic utility billing or the yearly property tax billing, or through a separate billing system. To avoid added overhead cost and to facilitate collection of bills, it is usually preferable to attach the charge to an already existent billing system. This type of user charge is the most efficient and least costly to administer.

A progressive user charge represents an attempt to correlate costs and service by charging the resident according to the amount of waste he generates. The assessment can be calculated in two ways: (1) a charge for each container collected or (2) a minimum charge that would cover collection of a certain number of containers plus an extra charge for each additional container.

The first method of assessing progressive charges is well illustrated by the system which requires that plastic bags sold by the collection agency be used, with the charge per bag including both the collection costs and the cost of the bag. On the whole, this approach does not achieve the objective of relating charges to costs, since the increase in collection costs per additional container is not a linear one. The cost of loading the second or third bag does not equal the cost of driving, stopping, and loading the first bag. Under this system, the high-volume user subsidizes the low-volume user.

The second method of assessing progressive charges is more equitable than the first, but it is more difficult to administer. It requires a more complex accounting system to keep track of customers' use of extra containers. A serious problem is controlling the system so that customers get billed for only the number of containers they are using and collectors know how many containers are to be collected from each customer. These administrative difficulties can be alleviated by use of specially marked containers. The distribution of the containers provides a record of how many containers a customer uses, and collection of only specially marked containers guarantees that no extra waste is collected.

ADVANTAGES AND DISADVANTAGES

Tax financing

The primary advantage of financing solid waste systems via tax revenues is its simplicity. There is no need to develop a billing and collection system, and payment is virtually guaranteed. Including the cost of solid waste service in the local property tax is advantageous from the householder's viewpoint, since that makes the cost deductible from State and Federal income taxes.

The disadvantages are that the amount budgeted for solid waste management often does not cover the operating costs of the system or allow for proper capital replacement policies. The result is that many of these systems must use equipment that is old and costly to maintain.

The use of a specific tax levy can avoid these problems if the fund is adequate to cover operating and capital replacement costs and is truly protected from being used for anything but solid waste management.

User Charge

The advantage of a user charge is that it enables localities to balance revenues with the cost of providing solid waste services. This situation makes it easier to justify rate changes when needed, because the claim of profit or loss can be documented. The close balance of cost and user charges, together with citizen awareness of the cost of the solid waste service, can lead to improved system efficiencies by forcing the solid waste operation to be run as a business with visible operating efficiency.

The primary disadvantage of a user charge is that it is more complex to administer than tax financing. There is the additional problem that, if the user charge is based on the number of containers collected, citizens may overfill containers or engage in illegal dumping to minimize their solid waste bill.

OTHER CONSIDERATIONS

In administering a user charge system, some provisions should be made for persons who are unable to pay the fee. One method is to allow the aged and indigent to pay a reduced charge, provided the reduction is applied for and verified by the appropriate public body.

CONCLUSIONS

Regardless of the financing method selected, three things are essential to achieving the maximum benefits of the system. First, good management and an accurate cost accounting system are needed to enable the collection agency to establish a cost-effective operation. Second, the funds collected for the financing of the system should be set aside in a dedicated fund so that they are available as needed for capital replacement and operating expenses. Third, the revenues received should be reflective of the cost of the service provided. Otherwise, the necessary amount of operating revenue may not be produced and awareness of the cost of service among the users is not fostered.

Because of the many factors impacting on collection costs, none of the financing methods described above can be precisely equitable nor would some communities desire them to be. In many cases one sector of the population subsidizes service to another sector by paying a price higher than the service actually costs. While it remains the province of individual communities to make such determinations, it is the right of the citizens to know about them.

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation environmental effects decisions collection

Capital Financing

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation environment transport processing disposal

Estimates of cumulative expenditures over the next 10 years for solid waste management range from $1.0 to $7.5 billion. These sums will be spent to construct new solid waste facilities and maintain and upgrade existing ones. This immense capital expenditure is, in part, the result of the need to conform to new Federal and State regulations, the development of more capital-intensive systems, and public demands about the environment. Financing these expenditures has become an increasingly complex and demanding task for municipalities.

Municipalities commonly draw from two basic sources to obtain capital for facilities and equipment: borrowed funds and current revenues. A third alternative is to contract with private firms for the service and shift the capital-raising burden onto them. The decision facing the local government manager is which of these alternatives is the best for his situation—the local conditions and needs. The decision will be controlled by such factors as the financial status of the city, voter attitude, legal constraints on debt limits or long-term contracts, and the magnitude of the project to be undertaken.

ALTERNATIVES

The basic sources of capital considered here are these:

1. Borrowing
    - General obligation bonds
    - Municipal revenue bonds
    - Bank loans
    - Leasing
2. Current revenue capital financing
3. Private financing
    - Industrial revenue bonds
    - Leveraged leasing

General Obligation Bonds

Among all public borrowing mechanisms available, general obligation (GO) bonds are, in general, the most flexible and least costly alternative. The issuing municipality guarantees a GO bond with its full faith and credit based on its ability to levy on all taxable real property such ad valorem taxes as may be necessary to pay the principal and interest on the bonds.

A GO bond requires no technical or economic analysis of particular projects to be funded. Small projects may be grouped to obtain capital, making GO bonds an ideal funding mechanism for solid waste facilities in small and medium-sized communities.

The transaction costs attendant upon the issuance of a GO bond impose a benchmark minimum of $500,000 on the debt issuance, as any amount below this level would prohibitively increase the per dollar cost of the lien. If total capital requirements of a small or medium-sized community are less than $500,000, it must adopt an alternative financing mechanism, such as private capital borrowing or leasing of equipment and facilities.

Municipal Revenue Bonds

A mechanism that is often used to circumvent the constraints associated with GO bond issuance is the municipal revenue bond. A revenue bond is issued to finance a single project with revenue-producing services.

Revenue bonds do not have the full faith and credit clause. Rather, they pledge the net revenue generated by the project to guarantee payment. The increased risk associated with revenue bonds yields a correspondingly higher interest rate. Also the coupon rates on revenue bonds are more volatile and depend strictly on the revenue-generating capacity of the project being financed. Revenue bonds require extensive bond circulars describing the economics of the project.

Bank Loans

A municipal bank loan ought not to be considered an alternative to long-term bond financing. However, relatively small-scale capital requirements may be met in the short run (5 years or less) at a low cost by securing a bank loan.

The most typical use of bank loans in the solid waste field has been to supply short-term funding for rolling stock. Since interest on a bank loan to a municipality is tax free to the bank, the corresponding interest will compare favorably with the coupon on a GO bond.

Municipalities often use bank loans to stabilize cash flow, and occasionally large cities use bank notes in anticipation of a bond issue. The notes, often substantial if arranged with a large bank, are refinanced as they expire. A medium-term source of funding is thus provided.

Leasing

In lease agreements, the leasing company (the lessor) purchases and holds title to the equipment and the lessee pays rent for the use of it during the lease term, usually not more than 5 years. Lease agreements in the solid waste area have usually been arranged by local equipment representatives, who place the financing with either a bank or leasing company. Currently, interest rates on lease agreements are averaging between 9 and 18 percent of the capital cost. Often, stipulations will be included in the contract agreement which allow the city to purchase the equipment at "fair market value" at the end of the lease.

The use of leasing by private solid waste companies is quite prevalent. Small private collection companies that are trying to expand their business may find themselves in a cash flow bind and use this type of financing extensively. Leasing is not so unprofitable for them because the cost of leasing can be written off as a business expense for tax purposes.

Current Revenue Capital Financing

The most common method for obtaining capital equipment for use in a solid waste system has been to buy it as needed. The principal advantage is simplicity, with no institutional, informational, analytical, or legal arrangements required. This method, however, is dependent on the ability of the community to generate surplus capital.

In the solid waste area, current revenue financing has been used mainly for collection vehicles and selected landfill disposal systems. Municipalities that dispose of solid waste using landfills are usually able to maintain the system with current revenues. Equipment replacement is not likely to be a major expense and can be handled periodically. Land can be leased or purchased as an investment. On the other hand, municipalities requiring either extensive upgrading of their systems in the short run or a capital-intensive solution to solid waste problems will have to raise capital by borrowing or by contracting with a private firm.

Private Financing of Municipal Solid Waste Systems

A third alternative for a community seeking to obtain capital equipment for use in solid waste management is to contract with a private firm to raise the capital, purchase the equipment, and operate the system. This approach relieves the municipality entirely of having to devote capital funds to solid waste management and presumably provides the most long-term flexibility.

Industrial Revenue Bonds

An industrial revenue bond is issued by a municipality for or on behalf of a private enterprise. The municipality technically owns the facility and equipment, which it leases to the private firm. The lease payments are specified to meet the scheduled payments of debt and interest on the bond. The municipality thus acts as a vehicle through which a corporation may obtain low-cost financing. If payment arrangements between the corporation and the municipality are structured as an installment sale, the corporation may claim ownership for tax purposes. This gives the corporation a tax benefit in the form of accelerated depreciation or the investment tax credit.

The ability of a municipality to issue an industrial revenue bond is dependent on enabling legislation from the State. Forty-four States now allow their municipalities to issue industrial revenue bonds.

A major stumbling block of industrial revenue bonds concerns a community's ability to sign long-term contracts with corporations, guaranteeing a minimum supply of solid waste. While the security of these issues requires long-term agreements, many States do not permit communities to enter into long-term service contracts.

Leveraged Leasing

Leveraged leasing is technically not a financial instrument. Rather it is a financial package that combines several financial options. The concept is based upon the benefits (lower long-term capital and interest costs) that accrue to a city if a financial intermediary, a corporation or individual, is interposed between a long-term source of capital and the municipality.

Leveraged leasing, using tax-exempt funds as a debt source, is a new concept that has been applied only twice in the public sector. Its future, however, is promising and it has stirred a great deal of interest in the public financing investment community.

Leveraged leasing is a most complex mechanism to initiate. It involves two major participants, a financial intermediary (lessor) and a city (lessee) (Figure 2). It differs from traditional leasing in that both the lessor and the city provide capital funds to purchase the asset. Usually, the lessor puts up 20 to 30 percent of the cost of the asset and the city finances the remaining portion through a typical borrowing method.

The financial intermediary acquires the tax advantages of ownership, and therefore can pass on to the city a very low interest rate (lower than GO bond interest rate) on his share of the cost of the asset. He is able to provide funds to a municipality at a very low interest rate because he is the owner of the entire facility from a tax standpoint and he can depreciate the investment and, in addition, claim a 7-percent investment tax credit if the facility is run by a private corporation. Essentially, the depreciation and tax credit act to shelter the financial intermediary's other income, which allows him to receive an adequate after-tax return on his initial investment in the asset.

The characteristics of each means of financing solid waste systems should be examined so that the means best suited to the particular community will be selected (Table 12).

ADVANTAGES AND DISADVANTAGES

General Obligation Bonds

Advantages:

- One of the most flexible and least costly public borrowing methods
- Requires no technical or economic analysis of particular projects to be funded
- Small projects may be grouped to obtain capital
- Ideal mechanism for small and medium-sized communities
- Least difficult to market

Disadvantages:

- Requires voter approval, and elections may be expensive
- Must not exceed municipality's debt limit
- Issuing jurisdiction must have power to levy ad valorem property taxes
- Transaction costs impose a benchmark minimum of $500,000 on amount of debt issuance
- Capital raised becomes part of general city treasury, thus other city expenditures could draw on amount, unless specifically earmarked for solid waste
- Since careful project evaluation is not required, decision-makers may be unaware of technological and economic risks
- Ease of raising capital is a deterrent to change in existing public/private management mix; little incentive for officials to consider use of private system operators

Municipal Revenue Bonds

Advantages:

- Project revenues guarantee payment
- Can be used by institutions lacking taxing power, such as regional authorities and nonprofit corporations

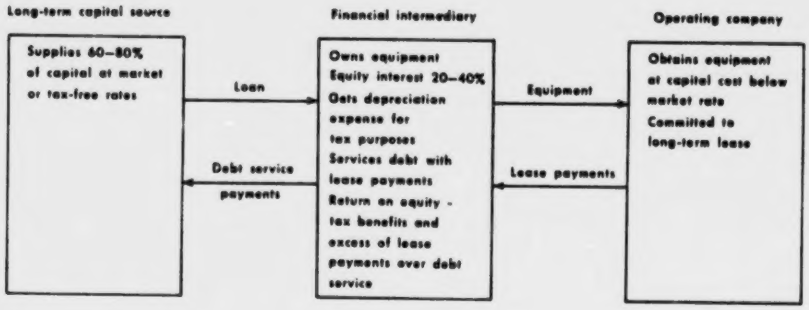
Long-term capital source
Supplies 60–80% of capital at market or tax-free rates
Loan
Debt service payments
Financial intermediary
Owns equipment
Equity interest 20–40%
Gets depreciation expense for tax purposes
Services debt with lease payments
Return on equity - tax benefits and excess of lease payments over debt service
Equipment
Lease payments
Operating company
Obtains equipment at capital cost below market rate
Committed to long-term lease

FIGURE 2. A typical leveraged leasing structure uses a financial intermediary to transfer the capital from the capital source. The intermediary leases the equipment bought with the capital to the operating company and uses the lease payments to service the debt to the capital source. Source: RESOURCE PLANNING ASSOCIATES, INC., A study of alternative financing methods for solid waste facilities and equipment. U.S. Environmental Protection Agency, 1974, p. 86. (Distributed by National Technical Information Service, Springfield, Va.)

- Does not require voter approval
- Is not constrained by municipality's debt limitations

Disadvantages:

- Effective minimum issue of $1 million, thus only useful for capital-intensive projects
- Information requirements of the bond circular are extensive, which may cause delays in raising capital
- Technical and economic analysis of project must be performed by experts outside the municipal government
- Cost is higher than GO bonds
- Can be used only for specific projects

Bank Loans

Advantages:

- Small-scale capital requirements for short-term funding (5 years or less)
- Relatively low interest cost because interest paid by municipality is tax free to bank
- Some medium-term funding applicability since notes may be refinanced as they expire
- Source of funds on short notice
- No external technical or economic analysis required
- Essentially no minimum
- Relatively inexpensive
- Voter approval generally not required
- No debt ceilings
- Can be used by institutions lacking taxing power

Disadvantages:

- Low maximum
- Short term
- Not useful for capital-intensive projects

Leasing

Advantages:

- Useful as interim financing for equipment needed before appropriations or long-term capital arrangements can be made
- Reduces demand on municipal capital outlays since original capital is raised by private corporation
- Negotiating agreement is simple and fast
- Only certification required is assurance of municipality's credit standing

Disadvantages:

- Relatively high annual interest rate (9–18 percent)
- Amount of capital is usually limited
- Lease terms are generally 5 years
- Some States prohibit municipalities from entering multiyear, noncancellable contracts

TABLE 12

CHARACTERISTICS OF CAPITAL FINANCING METHODS AVAILABLE FOR SOLID WASTE MANAGEMENT FACILITIES *

Parameter	Types of financing						
	General obligation bonds	Municipal revenue bonds	Municipal bank loans	Leasing	Leveraged leasing	Current revenue capital financing	Private financing
Complexity of application	No project information required No project analysis required Short lead time	Most complex Bond circular must contain detailed economic and technical information that has been certified by outside consultants Requires more time to arrange	Less complex than bonds, particularly if community has bank line of credit Very short lead time No need for external advice or certification	Relatively simple Minimal analysis required Very short lead time	Legally complex New to public finance May require IRS ruling in beginning, therefore requires 6-month lead time	Least complex of municipal finance alternatives	Problems may include locating acceptable firm, negotiating contract and proposed facilities site, public job reductions, other organizational or management issues Technical and economic analysis performed by private firm
Ability to raise capital	Minimum $500,000 due to fixed transaction costs but can combine several smaller unrelated projects Function of community credit, not a function of particular project	Minimum $1,000,000 due to heavy fixed transaction/administrative costs In pure form, not suited for technologically risky projects Maximum is function of projected project revenues	Absence of heavy fixed transaction costs makes it useful for smaller dollar needs Maximum limited by lending capacity of bank Better for short- and medium-term loans than bond	Good for small short-term (5-year) loans Applicable to specific pieces of equipment, especially rolling stock	Raises 20 to 50 percent of the capital required In pure form, not suited for technologically risky projects Good potential	Current revenue often not available in amounts necessary for major capital expenditures	Depends on credit rating of firm and soundness of project Firms may be limited to smaller amounts of capital than municipality with general obligation bond
Cost of capital	Lowest interest rates for long-term capital Interest cost 2-3 percent less than corporate bonds Indirect costs include bond counsel and possibly financial consultant, but costs are relatively low	Somewhat higher than general obligation bond Is directly related to the probability of maintaining adequate revenue Municipality can minimize cost of capital by giving revenue bond the risk attributes of a general obligation bond Indirect costs higher than for general obligation issue	Similar to general obligation bond, in terms of risk and security but affected by loan size and term	High effective annual interest (12-18 percent) Same rate for private, public lessees.	If city provides the remaining 50 to 80 percent capital required for the project, the cost of the money is lower than with general obligation bond financing Indirect costs absorbed by lessor	Opportunity cost, other social benefits foregone	Higher for private firm than for municipality Could be lowered through mechanisms like industrial revenue bond or leveraged leasing
Constraints on use	Voter approval often required Legal debt ceiling may exist Can only be used by jurisdictions with taxing powers	Can be used only for specific projects Good only for relatively large amounts of long-term capital Must be managed by district authority or agency Requires stable, long-term source of revenue	Shorter loan terms than bonds Smaller dollar amounts than bonds	Short term Small dollar amounts State-imposed restrictions on municipalities about signing multi-year noncancellable leases	State restrictions on city's signing multi-year contracts Public decision-makers unfamiliar with concept	No legal constraints Economic constraint of amount of available capital	Legal constraint against communities signing long-term noncancellable contracts Insufficient profit potential to compensate firm for risk Administrative legal complexities of potential mechanisms industrial revenue bonds and leveraged leasing Mechanisms available do not benefit marginal firms

* Source: RESOURCE PLANNING ASSOCIATES, INC. A study of alternative financing methods for solid waste facilities and equipment. U.S. Environmental Protection Agency, 1974. p. 86. Available through National Technical Information Service, Springfield, Va. In press.

- **City will not own asset unless it purchases facility upon completion of leasing period**

Leveraged Leasing

Advantages:

- **Reduces demand on municipal capital funds**
- **Interest rate on entire financial package may be lower than GO bond rates**

Disadvantages:

- **Legally complex**
- **City will not own asset unless it purchases facility upon completion of lease period**

Current Revenue Capital Financing

Advantages:

- **Least complex mechanism available**
- **No need for formal financial documents**
- **No consultant or legal advice required**

Disadvantages:

- **No cost in the conventional sense, but higher taxes result**
- **Communities frequently lack ability to raise capital**
- **Current taxpayers have to pay for the entire capital cost of a system that will be used far into the future**

TABLE 13

EXAMPLE OF COSTS TO FINANCE $10 MILLION THROUGH GENERAL OBLIGATION BOND, MUNICIPAL REVENUE BOND, AND REVENUE BOND AND LEVERAGED LEASING *

(In thousands)

Item	General obligation bond (5.7%)	Municipal revenue bond (6.25%)	Revenue bond/leveraged leasing † (4.88%)
Front-end costs:			
Rating agency fees	$ 3	$ 5	$ 5
Commission to underwriter	150	250	170
Counsel to underwriter	5	7	7
Counsel to city	10	10	11
Bond counsel	18	40	30
Accountants' fees	8	8	8
Initial trustee fees	6	6	6
Printing and engraving	30	40	35
Third party	—	60	60
Debt service reserve	—	817	572
Election cost	‡	—	—
Total	$ 230	$1,238	$ 904
Net proceeds to city	$9,770	$8,762	$9,096
Yearly cost to city §	$ 848	$ 883	$ 788
Effective debt service rate ¶	8.7%	10%	8.6%

* Industrial revenue bond costs are not detailed, since all costs are passed through to the involved corporation. The assumed interest rate for each debt instrument was arbitrary. The actual rate will vary according to the credit worthiness of a project (or city) and the current capital market conditions.

† $7 million by revenue bond, $3 million by lessor. The interest rate is the weighted average cost of capital for the financial package.

‡ Election costs are unknown.

§ This is the dollar amount the city would have to pay to retire and pay the interest on the debt. It was assumed that a city made steady payments for the life of the financing to retire the debt. The payments would be made semiannually for 30 years.

¶ The effective debt service rate is the yearly percentage cost to the city. This is calculated by dividing the yearly cost (interest plus debt retirement) by the net proceeds a city receives.

- Most prevalent form of solid waste capital financing because so little capital has been spent
- Solid waste projects must compete with other municipal demands

Private Financing

Advantages:

- Municipality not involved in external consulting
- Municipality need not borrow capital

Disadvantages:

- Municipality must locate acceptable firm and negotiate contract
- Higher cost of capital reflected in system charges
- There may be legal constraints preventing signing of long-term contract
- There may be displacement of city employees

COMPARATIVE COSTS

When comparing costs of different financial mechanisms, it is important that one not fall into the trap of just reviewing coupon (interest) rates. Coupon rates understate the true costs a city must pay on the capital it borrows. Rather, the municipality should compare the effective debt service rate and the yearly cost to the city on the funds it finances (Table 13).

CONCLUSIONS

Because of its simplicity, current revenue financing is the means most commonly used by municipalities to finance collection vehicles and landfill disposal systems. This method, however, is dependent on the ability of the community to generate surplus capital. Thus it is frequently inadequate for capital-investment projects.

For a project requiring capital in excess of $500,000, a GO bond is probably the best choice, provided it has voter support and does not exceed the legal debt limit.

For projects requiring capital in excess of $1 million, the municipal revenue bond is a desirable source of financing. Although it is a complex approach and may take a great deal of time to arrange, it forces the community to plan carefully, to design a low-risk project, and to conduct a thorough economic analysis in order to assure the necessary revenue-generating capability.

Finally, leveraged leasing should be considered as a source of long-term asset financing. Its disadvantages—newness and complexity of application—seem to be more than offset by the potential cost savings to the municipality.

Public and Private Operation of Processing and Disposal Facilities

Like solid waste collection, processing and disposal are functions performed by both the public and private sector. With the increasing amounts of municipal solid waste generated each year, many communities are faced with the task of developing new facilities to handle these wastes. In planning for new facilities, whether they include shredding, baling, or resource recovery facilities, or merely additional sanitary landfill space, communities will be considering not only which technology to choose but who should own and operate the facilities.

ALTERNATIVES

The institutional alternatives available range from totally public to totally private operation with many variations in between. Several of these alternatives are similar to those described in regard to collection operations.

- Public (municipal) operation, usually under the control of a governmental department such as the department of public works.
- Public corporation, authority, or utility, usually serving a multijurisdictional or regional area, financially self-supporting, and administered separately from other agencies of city government.
- Private firms with a contract or some type of franchise from the local governmental unit.
- Private firms operating independently of the local government.

Possible public-private combinations include situations in which the local government owns the facility and a private firm operates it under contract to the government. Another combination is the case in which a private firm or individual leases the facility to the local government, who actually operates it.

In communities with several processing and disposal facilities, a number of these various alternatives may be used, with some sites private and others public.

ADVANTAGES AND DISADVANTAGES

While solid waste processing and disposal may be executed by either the public or private sector, it is the responsibility of the government (usually at the local level) to insure that environmentally acceptable facilities are available and to plan for future needs. As solid waste processing and disposal technologies become more sophisticated, cities must take into consideration such things as availability and cost of capital, technological risk, and the degree of management expertise required for a given project. Cities must examine these factors in deciding whether to own and operate their own facilities or contract with a private firm for these services. The following discussion presents the advantages and disadvantages to a city of involving private firms in the processing and disposal function.

One advantage associated with private ownership and operation of processing and disposal facilities is that the local community does not have to finance the system. This is an important factor if the city's borrowing power is limited. The involvement of a private firm also insures that a community does not bear the entire risk associated with implementing new kinds of technology.

By utilizing private firms the city avoids the administrative details associated with operating the system. Also private firms generally have greater flexibility in management than public agencies. For example, a private firm can adjust its manpower requirements more quickly than a city, which must be responsive to pressures by labor unions to protect jobs.

Private firms can also make long-range plans for land acquisition and additional facilities without city council or voter approval and are not constrained by a yearly budget cycle.

Land disposal site acquisition may be easier for private firms, because there is less publicity when a private firm purchases land than when a city does. It may therefore be possible to avoid turning site location into a political issue.

The primary disadvantage of private sector facilities is that the city may not have sufficient control over the price it has to pay for disposal, especially if private facilities are the only ones available in a community. This problem may be alleviated somewhat if the city's contract with private firms provide safeguards against unreasonable rate increases.

Private processing and disposal facilities may cost more than equivalent public facilities because of the profit motive. Private firms also pay taxes, whereas a public facility is tax-free. In addition, if the technology for a type of facility is very new, there may be only one or two companies available to implement it, and with such limited competition there is little incentive to keep costs to a minimum.

CONCLUSIONS

It is the responsibility of the public sector to insure that solid waste processing and disposal facilities are provided and operated in an environmentally acceptable manner, whether or not they are actually owned and operated by a unit of government. In deciding whether to own and operate a given facility or to contract with the private sector for this service, cities must evaluate factors such as their ability to raise capital, the degree of technological risk involved, the management expertise required, and the expected operating cost.

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

COLLECTION

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

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Point of Collection

Probably the aspect of service level most apparent to the citizen is the point of collection, that is, where the waste is picked up. The decision on this issue affects other aspects of the collection system design such as crew size and storage, and is ultimately a controlling factor in the cost of providing the collection service.

ALTERNATIVES

The main issue is who should be the one to carry the refuse from the house to the curb. There are two basic options available:

1. Curbside/alley collection requires the resident to place the solid waste at the curb or alley for collection and to retrieve any empty storage containers.
2. Backyard collection, which usually takes one of four forms:

   Tote barrel—the collectors walk to the storage containers and empty into an intermediate container, leaving the storage containers in place.

   Set out—the collectors carry the refuse in the storage containers to the curb for collection, and the resident retrieves the containers.

   Setout/setback—the collectors carry the refuse containers to the curb for collection and return them to their storage place.

   Satellite vehicle system—small-capacity vehicles are used to traverse long distances between the refuse containers and the larger vehicle (e.g., street to backdoor via driveway).

Approximately 60 percent of the collection systems in the United States are curbside and alley; 40 percent are backyard. Recent trends, as evidenced in St. Petersburg and Tampa, Florida; Atlanta, Georgia; Fort Worth, Texas; and Akron, Ohio, are away from backyard and toward curbside. Some communities provide a choice of curb or backyard service and charge at a different rate for each.

COSTS

Time spent walking to the containers or carrying them is costly, and cost factors have brought pressures for greater efficiency in solid waste collection. Curbside/alley collection yields the highest productivity. A savings of 50 to 55 percent may be achieved by using curbside/alley rather than backyard collection (Table 14).

TABLE 14

COST FOR ONCE-A-WEEK COLLECTION USING TWO-MAN CREWS, BY POINT OF COLLECTION AND INCENTIVE SYSTEM, IN FOUR CITIES, 1973 *

City	Incentive system	Point of collection	Cost per ton †	Percent difference
1	task	curb/alley	$ 9.53	
2	task	backyard	19.26	51
3	8 hours	curb/alley	8.72	
4	8 hours	backyard	18.41	55

* Source: ACT SYSTEMS, INC. A study of collection productivity using various collection methodologies. Unpublished data.

† Labor rates for the cities have been normalized to permit intersystem comparisons; therefore, these figures do not reflect actual collection costs.

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OTHER CONSIDERATIONS

Effect on Collectors

Due to the increased distances the solid waste must be carried, the work in backyard collection is physically more demanding than in curbside collection. The result is that many backyard collection systems have a difficult time recruiting collectors and have a high turnover rate. In addition, the greater risk of backstrain and the hazards in yards from such things as clotheslines, holes in the ground, objects in the grass (toys, rakes), and dogs, increase the rate of collector injuries in backyard collection systems.

Separation of Wastes

If the citizens are required to separate their solid waste, the different classes of waste will normally be collected separately. It is not necessary to use the same point of collection for all service; newsprint could be picked up at the curb or alley and other refuse at the backdoor. Because of the added cost of backyard collection and the desire to make the separate collection of reusable items as self-supporting as possible, curbside/alley collection is recommended for these wastes.

Effect on Residents

In some communities, citizens will express a preference for backyard collection even though it costs more. In these communities, an evaluation of the true cost difference between backyard and curb/alley collection should be performed so that the implications of choosing the more costly service are recognized.

In other communities, where curbside/alley service is the custom, the effects of this policy on the aged and handicapped should be examined. In cases where individuals are unable to deliver their solid waste to the curb, special service should be arranged.

CONCLUSIONS

On the basis of increased efficiency and productivity and reduced collector injuries, the Environmental Protection Agency recommends the use of curbside/alley collection.

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Frequency of Collection

For health and sanitation reasons, the minimum acceptable frequency of collection for residential wastes containing putrescibles is once a week. In certain situations, particularly in inner-city areas, dense population and seriously restricted storage space often combine to require more frequent service.

ALTERNATIVES

There are three acceptable choices of collection frequency: once a week, twice a week, and more than twice a week. It is estimated that 45 percent of the urban systems have once-a-week service. They are concentrated on the West Coast, the Midwest, and the Northern States. Systems with twice-a-week collection are primarily in the Southern (especially Southeastern) and Mideastern States and also account for 45 percent of the urban systems. More frequent service, provided in about 8 percent of urban communities, occurs in densely populated areas such as parts of New York City, which receive daily or twice-daily collection.

COSTS

An increase in frequency of collection will increase costs due to the increased time spent collecting on the route each week. A comparison of collection costs for four cities shows that savings of 13 to 42 percent may be made by collecting once a week rather than twice a week (Table 15).

ADVANTAGES AND DISADVANTAGES

The primary advantage of once-a-week over twice-a-week collection is that it costs less and uses less fuel. For relatively efficient systems, 23 to 33 percent fewer vehicles are required for once-a-week collection. Fuel consumption is about 30 percent less. The reduction in trucks, manpower, and miles driven can cut costs by as much as 50 percent.

The advantage of more frequent collection is that it reduces littering in urban areas

TABLE 15

COST OF CURBSIDE COLLECTION BY FREQUENCY OF COLLECTION AND CREW SIZE, IN FOUR CITIES, 1973 *,†

City	Crew size	Frequency of collection	Cost per ton ‡	Percent difference
1	1	1	$ 8.29	43
2	1	2	14.49	
3	3	1	12.82	13
4	3	2	14.67	

* Source: ACT SYSTEMS, INC. A study of collection productivity using various collection methodologies. Unpublished data.

† Using task incentive system.

‡ Labor rates for the cities have been normalized to permit intersystem comparisons; therefore, these figures do not reflect actual collection costs.

and reduces the amount of space required for storing solid waste.

OTHER CONSIDERATIONS

Fly Generation

Studies in California have shown that frequency of collection can be an important factor in the control of flies, with twice-a-week collection more effective in fly control than once-a-week collection. However, control of flies is more closely linked to proper selection and maintenance of storage containers than to frequency of collection. Use of proper containers to retard fly production makes once-a-week collection of garbage acceptable.

Separation of Wastes

When citizens are required to separate their solid waste, a frequency should be set for each waste category. For instance, newsprint may be collected once a month, while other household refuse is collected once a week. Each decision on frequency should be made independently, taking into consideration the characteristics and storage requirements of each waste type.

CONCLUSIONS

On the basis of cost effectiveness, the Environmental Protection Agency recommends once-a-week collection unless it is prohibited by inadequate storage.

REFERENCES

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2. SHUSTER K. (Office of Solid Waste Management Programs.) Analysis of fuel consumption for solid waste management. Unpublished data, Jan. 1974.

Storage Containers

The types of containers used for household storage of solid waste have in recent years been a subject of active discussion and study. In every collection system, the types of containers that residents may use should be defined either by ordinance or regulation. This will inform the citizen of what is expected of him and will facilitate enforcement. The problem here is to decide which containers are best under the conditions of the particular area.

ALTERNATIVES

There are five main categories of containers:

1. Stationary storage bins are permanent, immovable structures used either to surround another type of container or for direct storage of solid waste.
2. Fifty-five-gallon drums are large, heavy, cylindrical containers, usually having no lids. They are commonly discarded oil or chemical drums.
3. Containers designed for mechanized collection come in a great variety of shapes and sizes and are used with specialized collection vehicles which eliminate the manual loading of solid waste into the vehicle.
4. Standard, lightweight, 20- to 32-gallon metal or plastic cans are readily movable rigid containers which normally come equipped with lids.
5. Paper and plastic bags are usually used as liners for rigid containers. These are discussed separately, in the chapter following this one.

ADVANTAGES AND DISADVANTAGES

Stationary Storage Bins

Stationary storage bins (most frequently made of concrete) are inefficient and unsanitary and sometimes constitute a fire hazard. They require the collectors to carry out the time-consuming, hazardous, and costly procedure of shoveling the solid waste out by hand. Usually they are hard to clean out and are not covered properly. Such bins are usually found at apartment buildings and low-income housing projects. A combination of the inadequacies of the bins plus insufficient maintenance or careless use frequently leads to a severe litter problem around the bins.

When the bins are used to house removable containers, the waste is easier to collect but pieces of it usually fall into the bins, and then both the bins and containers must be emptied.

For these reasons it is recommended that the use of stationary bins be discontinued.

Fifty-Five-Gallon Drums

A remnant of the backyard burning era, 55-gallon drums continue to be used as waste containers in many areas. Their use causes health and safety problems to the collectors as well as to the general public, and they contribute to lower collection efficiency and higher costs. Most of the difficulty stems from their weight and the absence of lids. The drums themselves weigh 35 to 40 pounds and so can nearly double the total weight usually lifted by collectors. This increases the risk of back injury and muscle strain. The size and shape of the drums also contribute to difficulty in handling; a drum that slips or is dropped can cause serious injury. Also, the drums are rarely covered and so collect rain and snow, adding even more weight. This moisture causes the waste to stick to the drum, requiring manual handling of the waste itself.

Coverless drums also cause health, safety, and odor problems. During the summer months, insects can breed in the waste. If rainwater works its way to the bottom of the drum, the metal eventually rusts through, allowing rodents to feed from the containers. As the rust progresses, sharp edges are formed which can injure the collector as well as others.

Since the drums are heavy, many collectors resort to the hazardous practice of picking out the waste by hand, or they may leave the waste for the next collection.

Because they are inefficient storage containers and could cause health and safety problems, EPA recommends that 55-gallon drums not be utilized as solid waste storage containers.

Containers for Mechanized Collection

Mechanized collection from bulk containers has long been regarded as an efficient and acceptable way of servicing apartment buildings and commercial establishments. Several of the more efficient residential solid waste systems in the United States use clustered storage and mechanized pickup by which more than one residence can be serviced per stop. Scottsdale, Arizona, uses 80-gallon plastic containers for single-family units, and 300-gallon plastic containers in alleys for four units. Both types of containers are emptied mechanically by a vehicle with an arm controlled by the driver, who never has to leave the cab. An interesting sidenote about clustering wastes is that containers for two families are not as acceptable to residents as four-family containers, since each resident knows whose waste is whose. With the four-unit container, anonymity is preserved. People also tend to oppose even the temporary storage of other people's solid waste on their property.

Where there are proper storage areas and sufficient access space, and economic analysis shows a cost savings could be achieved, mechanized collection should be considered. Further discussion of such specialized collection systems is provided in the section, "Residential Collection Equipment Selection and Crew Size."

Metal or Plastic Cans

The most commonly used storage container is the rigid galvanized metal or plastic can. These containers are acceptable when they are lightweight, not rusted through or cracked, kept reasonably clean, and have tight-fitting lids. Containers outside the 20- to 32-gallon range are usually not acceptable. Use of many smaller cans at each stop increases the handling time required to load the refuse into the truck while the use of larger or heavier cans increases the weight the men have to lift.

Other Types of Storage

Use of subterranean containers should be discouraged. They are extremely difficult for the collectors to lift out of the ground, and in the winter they can freeze to the ground, making it impossible to collect them. The extra time it takes to handle these containers lessens efficiency and increases costs. Maintaining the pits is difficult. Loose refuse can get down around the can and into the pit, attracting insects and rodents.

Makeshift containers, such as cardboard boxes, can also present problems because of awkward shape or size, or flimsiness, or because they do not tightly enclose wastes. Regulations on acceptable sizes and weights should be set so as to safeguard the collectors and prevent excessive slowdown of the work by the handling of awkward items.

OTHER CONSIDERATIONS

Fly Generation

Control of flies is closely linked to the adequacy of solid waste storage. If the storage containers are kept reasonably clean and have tight-fitting lids, and if all household wastes are kept in such containers, the problem of flies will be minimized.

Separation of Wastes

If the householder is required to separate his solid waste, there may be a significant impact on storage. With the exception of newsprint, which can be bundled and stored without containerization, any separation of either food wastes or reusable materials will require extra storage containers and space. This can become a critical problem if more than two or three categories of wastes are to be stored separately, or if the collection frequency is low, such as once a month.

CONCLUSIONS

The Environmental Protection Agency recommends the use of bulk containers designed for mechanized collection when multi-unit collection is involved. When collecting from individual housing units the use of properly maintained, lightweight metal and plastic cans, and paper and plastic bags is recommended.

Paper and Plastic Bags

Collection of residential solid waste is a labor-intensive activity, and the method of solid waste storage selected can have broad implications for the equipment and crew size used in a system. In recent years, paper and plastic bags have been increasing in popularity both as liners for rigid containers and as storage containers. In deciding whether or not the use of bags should become an integral part of the collection system, a city must examine whether with its present collection methods the benefits of using bags will outweigh the additional cost of the bags themselves.

ALTERNATIVES

Any bag selected should meet National Sanitation Foundation standards. For plastic bags, the standards include resin used, strength at folds and seals, film thickness with tolerances, film strength, bag dimensions, weight, and closures. The paper bag standards include material used, adhesives, tape, thread, capacity, and strength. The only change in these standards recommended by EPA is that the minimum film thickness for plastic bags be increased from 1.5 to 2.0 mils to help reduce punctures and tears.

ADVANTAGES

The advantages of paper and plastic bags for solid waste storage can be divided into three categories:

Economic Benefits

The acceptability of bag systems by labor forces is high. Compared to conventional containers, bags are easier to handle and carry, no lids have to be removed or replaced, no time or effort is required to dislodge the contents, no set-back motion is required, and there is less weight to be lifted. The result is faster, more efficient, and less costly service. Studies show that use of bags can result in collection cost savings of up to 35 percent per service, holding all other system characteristics constant. However, this will often not be sufficient to cover the cost of the bags (at 3¢ to 5¢ each). The increases in efficiency realized by introducing bags into the system are translated into reduced costs only when they are combined with other cost-saving measures such as reduced crew sizes or a switch from backyard to curbside service.

When used with backyard service, employing either tote barrels or satellite vehicles, bags will help reduce spillage and blowing litter but will not produce cost savings.

Esthetic Benefits and Convenience to Householder

When additional storage volume is needed, it is relatively easy to use additional bags. The bags are disposable, so conventional containers do not line the street after collection. Bags can eliminate odors and the cleaning of dirty containers. Collection is quieter because noise from conventional containers is eliminated and because the trucks remain on each street a shorter length of time. Because the bags can be closed, spillage of waste at the truck and blowing litter during loading is reduced.

Health Benefits

The fly population can be reduced or held in check because the bag can be closed against fly entrance. Although rats can enter bags, the use of bags will not attract rats to areas free of them.

Bags tend to minimize the collector's contact with the waste. They help to protect him generally from injury, disease, and toxic materials, although he must be careful to avoid injury from sharp protruding objects.

Empty bags are practically weightless compared to conventional containers. Less weight to lift should mean a lower incidence of back injuries and muscle strain among collectors and, consequently, less sick leave and medical expenses.

DISADVANTAGES

There are disadvantages to the use of bags as storage containers for solid waste: (1) replacing conventional containers with a sufficient number of bags costs more than continued use of the containers without the bags, and the distribution of the bags costs money (some of this cost can be offset by the savings in collection cost); (2) bags can fail (this can be minimized by using reasonably thick bags and by using them sensibly); (3) bags are susceptible to animal attacks (leash laws are an effective preventive measure as far as dogs are concerned); and (4) bags are not suitable for such items as branches, cardboard boxes, heavy objects, or objects with sharp or pointed edges (injuries can occur when sharp or heavy objects are hidden in bags).

OTHER CONSIDERATIONS

In a sanitary landfill, the compaction process rips open the plastic bags, allowing the contained waste to undergo normal degradation. The plastic bags themselves are nonbiodegradable, but this presents no real problem for the following reasons:

1. Settlement of the landfill mass, including the nondegradables, is caused by the process of decomposition of the biodegradables. (This decomposition of the biodegradables can result in gas production and leachate which require special measures to prevent air and water pollution. Thus, the degradables have a greater environmental impact than the nondegradables.)
2. Although the widespread use of bags will increase the amount of material entering the solid waste stream, the increase would be relatively small. A recent study supported by EPA determined that the average weight of solid waste in a plastic bag is about 15 pounds and the bag itself weighs about 0.1 pound. The additional waste load caused by the use of plastic bags is only about two-thirds of 1 percent based on total weight. Another measure of the effect of plastic bags is the increase in nondegradable waste. For typical residential waste (about 27 percent nondegradable) the increase would be about 2.5 percent. The same study determined the average weight of residential solid waste in paper bags to be about 20 pounds, while the bag itself weighs about 0.5 pound. The additional waste load caused by the use of paper bags is less than 3 percent by weight.

Paper and plastic bags are reduced to harmless products of combustion when burned in a properly designed and operated incinerator. Plastic storage bags currently do not contain polyvinyl chloride (PVC). This material should not be used in the manufacture of bags because of the potential to produce hydrogen chloride when burned, with resulting corrosion of incinerator equipment. In general, polyethylene and paper yield water and carbon dioxide when incinerated in the presence of an abundant oxygen supply.

CONCLUSIONS

Properly designed and manufactured paper bags, plastic bags, and paper bags with plastic liners are acceptable as storage containers for residential solid waste. Plastic bags should not contain polyvinyl chloride, should have a minimum thickness of 2 mils, and meet all other National Sanitation Foundation standards. The present advantages and benefits to society and our environment from their use far outweigh their few disadvantages. Paper and plastic bags offer economic and sanitary advantages which make them superior to rigid containers and present no significant problems when placed in a sanitary landfill or when burned in a properly designed and operated incinerator. The Environmental Protection Agency supports their use.

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Collection of Bulky Items

Collection of bulky items can be a problem in many places; often separate procedures are needed for collection of these items.

ALTERNATIVES

There are four methods of providing for bulky item collection:

1. Bulky items are collected along with other refuse using compaction vehicles and regular crews.
2. The homeowner calls the collection agency to request that the item be picked up, and the agency sets the date it is to be collected by a separate bulk-pickup crew.
3. Bulky items are collected periodically along defined routes comparable to the regular solid waste routes. Bulk collection is scheduled to cover the whole city in a designated time period, usually 1 week.
4. The resident sets out the bulky item and the refuse collection crew reports that it is there for pickup by a separate bulk-pickup crew.

ADVANTAGES AND DISADVANTAGES

Collection with Other Refuse

This system requires that the compaction vehicles be capable of handling the items and that the crew be able to lift them. It would not be feasible for one man operating a side-loading vehicle to collect a refrigerator. But the task would be a reasonable one for men using a rear-loading truck having a large enough hopper. The primary advantage of this system is that it is more economical than having a separate crew to collect bulky items. A disadvantage is that it does not lend itself to the charging of a fee for bulk pickup.

Request or Call-in System

This system has several advantages. The collectors need only go where there are pickups to be made, and proper scheduling makes it possible to concentrate pickups in compact areas. The result is an efficient system with good utilization of the collector's time. It also may very easily incorporate a pickup fee to cover collection costs. However, this system has serious drawbacks in inner-city areas where there are a large number of items set out to be collected and a lack of cooperation by the residents in requesting pickup.

Periodic Bulk Collection Along Defined Routes

This system works very well in inner-city areas where there are many pickups close together. But in areas where pickups are more scattered, this system can be wasteful since collectors must traverse streets where there is nothing to collect. Therefore the efficiency of the system varies according to the type of district in which it is used. A disadvantage of this method of bulk collection is that it is difficult to assess fees for the service.

Collection Crews Report Items, Separate Crew Collects

This alternative requires the use of radio communication, otherwise bulky items could sit outside for more than 1 day. Also, the sporadic reports from the refuse collectors are not likely to result in efficient routing of bulk-pickup vehicles. However, this system does insure the pickup of all bulky items.

CONCLUSIONS

The selection of the method of bulky item collection must be based upon the characteristics of the solid waste collection system (crew size and truck type) and the nature of the area being served (inner city or suburban, and income level). In any case, it is a service which must be provided.

Source Separation for Resource Recovery

The source separation of waste products which can be recycled through the manufacturing process is a growing phenomenon. Source separation is defined as the setting aside of recyclable waste materials (such as paper, glass, and metal containers) at their point of generation (the home, factory, office, or other place of business) by the generator. This separation is followed by the transporting of these materials to a secondary materials dealer or directly to a manufacturer by the generator himself, by city collection vehicles, by private haulers and scrap dealers, or by voluntary recycling organizations.

The source separation technique of greatest concern to municipal government decision-makers is separation by the generator followed by collection on a regular basis by a municipal or private collector. Presently this technique is employed almost exclusively for the collection of paper, largely because of the relative difficulty for both the homeowner and the city collection forces in implementing a multiproduct separation and collection system. For example, glass must be sorted by color and cans by ferrous and nonferrous types. While the growth in the numbers of citizen-run neighborhood recycling centers attests to the willingness of many people to participate in these activities, most public officials to date have not attempted to implement separate collection of more than newsprint or mixed papers, possibly because of the additional costs and complications of collection and the need to secure additional markets. Because little data is available on multiproduct separate collection, only the methods of separately collecting paper are discussed here.

Source separation of paper is feasible primarily for newspapers from homes, corrugated containers from commercial and industrial establishments, and printing and writing papers from offices. It is at these points that recyclable grades are generated in relatively homogeneous and concentrated forms. Since private haulers typically collect commercial and industrial wastepaper, a municipality is primarily concerned with newspaper source separation by residents. In some cases, where an appropriate market exists, mixed paper separated from other wastes by the residents can also be collected.

Over 125 cities in the United States are currently conducting separate paper collection programs, compared with only 3 such programs in 1970. This tremendous increase is due to many factors:

- The increases in disposal costs
- The shortages in raw materials which have led to an increase in secondary material prices
- An increase in environmental awareness and concern on the part of citizens
- The realization that separate collections are more effective in removing materials from the waste stream and far less costly than recycling centers operated by municipal employees

ALTERNATIVE METHODS OF SEPARATE PAPER COLLECTION

Separate Truck

There are two basic methods for separate paper collection currently in use. One, the more common, is the assignment of a separate vehicle to collect the paper.

System Description

Trucks. Standard packers, usually taken from the standby fleet, are the most common vehicles for separate collection. Van and open-bodied trucks may also be used. They are more expensive to operate than a standard packer, however, because they require an extra crew member to stack the paper inside the truck.

Crew Size. One man for a side-loading packer and two for a rear-loader are sufficient to collect paper. As mentioned above, a third worker is needed if trucks other than packers are used. Because of the increased cost of backyard collection, curbside or alley collections are recommended.

Routing. The paper collection vehicle can cover three to five normal collection routes in a single day, since there are fewer items to handle per stop, no storage containers to return to the curb, usually less than 100 percent participation, and even participating households may not place the paper at the curb every collection day.

Unloading Point. If the secondary materials dealer is within a reasonable distance, the truck unloads at his facility. Paper dealers in distant locations usually place a large van at the transfer station or disposal site into which the paper is loaded. This van remains at the site until it is full, at which point the dealer replaces it.

Frequency of Collection. Collections are usually monthly, twice a month, or weekly. EPA does not yet have comprehensive quantitative data on the relationship of frequency of collection with other factors such as participation rate and collection cost. There are indications that the more frequent the collection rate, the larger the quantity of paper collected. Costs will also be higher with more frequent collections, however.

Standardization of Collection. To achieve maximum cooperation from the householder, collection must be conducted on a regular basis. Citizens must be fully informed of what is expected of them (newspapers to be wrapped with twine, for example) and know exactly when the truck will be there (every Tuesday or every fourth Friday, etc.).

System Requirements

Capital Investment. Capital is required only for any additional collection vehicles the program necessitates. However, only 1 of 10 cities whose separate collection programs were studied for EPA by a private contractor had purchased a vehicle (a small packer in this case) for the program. Most of the vehicles used in separate collection have been either standby packers, normally used when a breakdown in the regular fleet occurred, older trucks retained after a new packer was purchased, trucks no longer used regularly because of rerouting, or other trucks simply not fully utilized. Two communities which collected regular refuse 4 days a week instituted separate collection on the 5th day using the same trucks normally used in their regular collections. In short, in the cities studied the institution of separate collection resulted in an increase in utilization of existing equipment rather than purchase of new equipment. The fact that this form of resource recovery can often be implemented with little or no additional capital investment is one of its most appealing aspects and an obvious reason for its rapid proliferation.

Maintenance, Operating and Overhead Costs. When a vehicle is used for separate collection these costs are incurred just as they are for any collection operation. There is probably less wear and tear on vehicles used only for separate paper collection, although this has not been documented as yet.

Labor. Separate collection requires that more hours be spent on the collection route. However, significantly, in all but 2 of 10 cities studied no additional labor was hired to implement separate collection. In these two cities, part-time employees were brought on when particularly heavy volume demanded it. It must also be noted that in every case studied, three-man crews were used only because it was standard collection practice to have three-man crews. As noted above, two-man crews are sufficient for paper collection. The additional labor hours and cost to the cities would have been considerably less had they not included the unneeded crewman.

Rack System

The rack or "piggyback" system of separate collection has been used by a private collector in San Francisco since 1962. Its use in Madison, Wisconsin, has received the most publicity, however; there piggyback collection was instituted by the city in cooperation with the American Paper Institute.

System Description

Truck Modification. To employ this system, racks which vary in capacity from ½ to 1½ cubic yards are installed beneath the body of the standard packer (Figure 3).

Collection Procedures. As in the separate truck method, bundled newsprint is placed at the curb. Collection of mixed paper by this method is not recommended due to the space constraints of the racks. A major advantage of the rack system is that the householder need not concern himself with which day paper will be collected. He simply puts separated paper next to his mixed-refuse containers on the regular pickup day. Refuse and paper are thus collected simultaneously.

Overloading. Compared with separate truck collection, the piggyback method has apparent advantages in that the route must be covered only once, whenever regular collection is performed. A drawback is the tendency of the racks to fill up before the body of the truck has been filled with mixed waste. In Madison, with a 60-percent participation rate (approximately 60 percent of the residents place newspapers at the curb on any given collection day), the crews must off-load the bins one or two times before the compactor body is full. To accomplish this with the least delay, the public works department stations bulk containers at strategic points in the collection areas. The crew members unload the paper into the bulk containers and proceed along the route. In Madison, approximately 10 minutes off the route is required for each unloading (driving time plus unloading). Although the amount of time spent on route has lengthened as a result, there have been no overtime costs.

New Equipment Developments. Presently there are experimentations by cities and waste haulers to improve the piggyback system by designing a rack which will hold a greater quantity of newspapers, thus reducing time off the route. Also, one equipment manufacturer has designed and will

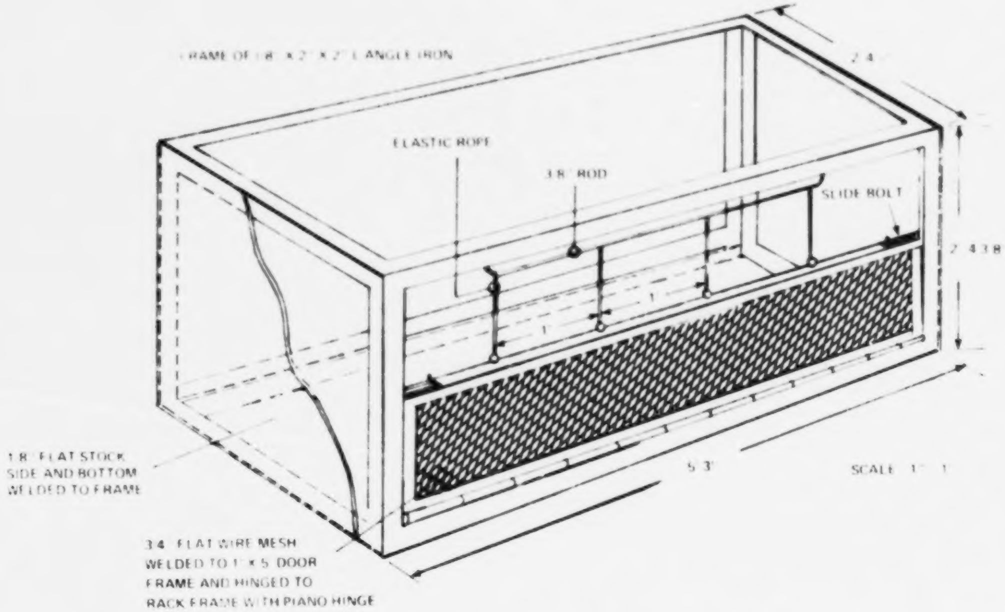
FRAME OF 1/8" × 2" × 2" L ANGLE IRON
2' 4"
ELASTIC ROPE
3/8" ROD
SLIDE BOLT
2' 4 3/8"
1'
1'
1/8" FLAT STOCK SIDE AND BOTTOM WELDED TO FRAME
5' 3"
SCALE 1" = 1'
3/4" FLAT WIRE MESH WELDED TO 1" × 5" DOOR FRAME AND HINGED TO RACK FRAME WITH PIANO HINGE

FIGURE 3. This is an example of a newspaper rack designed for installation beneath a packer truck for the collection of newsprint separately from residential solid waste. Source: CITY OF MADISON, Wis., Department of Public Works, Division of Engineering.

soon test a two-compartment truck for separate collection. These developments could significantly improve the economics of separate collection if they prove feasible.

System Requirements

Capital Investment. Costs for materials and installation of the racks range from $80 to $250 per rack. Madison's cost of $170 was about average.

Labor. Time-motion studies show that approximately 14 seconds are required to pick up and load bundled newsprint at each stop in addition to the approximately 5 to 15 minutes required for off-loading the paper when the racks are filled. In all cases studied there were no additional labor costs because employees had not been working a full day in normal waste collection.

Private Separate Collection

Private collection of wastepaper by a scrap dealer or waste hauler is one of the newer arrangements currently being tried in a number of communities on the West Coast. This system involves the least amount of time, money, and manpower on the part of the city. Indeed, for cities which contract for regular waste removal services, private collection of paper may be the only option possible.

City management may have no involvement at all, as in the case of San Francisco, where the private waste hauler carries out all facets of the program. Other communities have opted to share both the responsibility and the income from the program. Under this mode of operation, the city requests bids from private scrap dealers and/or waste haulers for the privilege of an exclusive contract to pick up source-separated paper. In return for a percentage of the income, the city usually agrees to support and publicize the program and to prohibit others from removing the paper through an antiscavenging ordinance.

COSTS

Due to the large number of variables it is difficult to give meaningful average costs for separate collection. Its economic viability depends to a large extent on factors such as the type of regular collection practiced (frequency of collection, size of crews, etc.), disposal costs, price received for the paper, participation rate of residents, availability of underutilized men and equipment, the efficiency with which the separate collection is carried out, and the extent to which regular vehicles are rerouted to take advantage of reduced waste volumes.

EPA has studied the collection costs of 10 communities with separate truck paper collection (Table 16). The analysis included labor, ownership and maintenance of equipment, and overhead costs for both the regular waste collection system and the separate collection subsystem. Credit was given for revenue from the sale of the paper and for a proportionate percentage of the variable disposal cost for landfill and incineration. In cases where the community paid a second party for disposal, the unit disposal charge was deducted for each ton of paper sold.

On the basis of March 1974 prices for the paper, the net effect of instituting separate truck collection on overall collection costs in these 10 cities ranged from a decrease of 23 percent to an increase of 16 percent. On the average there was a decrease of just over 5 percent. Many of the cities experienced little change in overall costs. It should be noted, however, that many of the programs were relatively new and not fully developed.

Interpretation of these results is difficult without additional knowledge about the conditions in each community studied. Specific information on the case studies is available from EPA, and a comprehensive report which will help cities estimate the economics of separate collection will be available in the latter part of 1974.

Cost data are also available on the rack or piggyback collection system in three cities (Table 17). Analysis of the data covered the same elements as that of separate truck systems. On the basis of March 1974 prices received for paper, separate rack collection was found to lower overall collection costs in each city. The average reduction was slightly less than with the separate truck systems.

Based on experience to date it appears that the specific conditions in each city would dictate the choice between separate truck and rack collection. For example, the ability to

TABLE 16

IMPACT OF SEPARATE COLLECTION BY A SEPARATE TRUCK ON OVERALL RESIDENTIAL SOLID WASTE MANAGEMENT COSTS *

Case study location	Collection and disposal cost prior to implementation of separate collection ($/ton)	Current paper price, 3/1/74 ($/ton)	Collection and disposal cost after implementation of separate collection †	
			($/ton)	(% change)
Dallas, Texas	$12.10	$43.00	$ 9.30	−23.1
Ft. Worth, Texas	13.50	35.00	11.80	−12.6
Great Neck, N.Y.	36.00	12.00	36.50	+1.4
Green Bay, Wis.	38.70	30.00	37.40	−3.3
Greenbelt, Md.	27.20	20.00	27.10	−0.4
Marblehead, Mass.	23.10	32.00	22.60	−2.2
Newton, Mass.	32.40	27.50	31.50	−2.8
University Park, Texas	14.70	43.00	12.50	−15.0
Villa Park, Ill.	13.50	36.00	12.40	−8.1
West Hartford, Conn.	26.30	40.00	23.90	−9.1

* Source: SCS ENGINEERS. Cost analysis of source separate collection of solid waste. Unpublished data.

† This takes into account the net of savings (revenue from wastepaper sold and diverted disposal savings) and incremental costs (labor and equipment) resulting from the separate collection program. In determining the latter, actual cost increases were considerad to the extent possible. For example, if a city had partially idle equipment that was put into full service to collect paper, only the variable costs (e.g., gasoline, maintenance, etc.) were considered an additional charge. Similarly, if workers already on the payroll were used to collect the paper only overtime charges, if any, were considered. However, if a city purchased, leased, or continued to maintain vehicles that otherwise would not have existed, a full cost was allocated to separate collection. Similarly any new hiring, permanent or part time, or retaining of labor that would otherwise have been discharged was allocated as a cost.

TABLE 17

ESTIMATED COST AND REVENUE FOR THE SEPARATE COLLECTION OF NEWSPRINT USING THE PIGGYBACK METHOD * (dollars per ton)

Case study location	Revenues from newspaper sales (3/74)	Diverted disposal savings	Total revenues savings	Incremental newspaper handling costs †	Net savings
Madison, Wis.	$32.00	$1.40	$33.40	$ 4.60	$28.80
New York, N.Y.‡	16.50	6.40	22.90	27.50	(4.60)
Sheboygan, Wis.	20.00	5.60	25.60	0	25.60

* Source: SCS ENGINEERS. Cost analysis of source separate collection of solid waste. Unpublished data.

† In determining incremental handling charges, *actual* costs were considered to the extent possible. For example, the equipment charges included were those for the racks (negligible when spread over the tons collected over the life of the racks) and any supplemental equipment such as containers placed along the route for off-loading of the news from the truck racks. Any incremental labor charges for handling these containers were also included. Though time spent collecting waste increased, costs were not allocated to separate collection unless overtime was paid or additional labor hired.

‡ Queens District 67 only.

fit racks on existing collection trucks, the number of men and trucks available, and the manner in which collection is carried out (routing, hours per day, and days per week worked by waste collectors) are major factors for municipal decision-makers.

How much newspaper is obtainable from residents in a city can be roughly estimated. The average per capita generation of municipal solid waste has been estimated to be 3.32 pounds per day. Approximately 6 percent of this is newspaper (Table 18). Therefore, for a city of 100,000 population with a 50-percent participation rate the approximate quantity of recoverable newsprint would be: 100,000 × 3.32 × .06 × .5 = 9,960 pounds per day or about 5 tons. At a price for old newspapers of $30 per ton, the weekly revenue would be $1,050.

SEPARATE COLLECTION SUCCESS FACTORS

Markets

Shortages of woodpulp, increased wastepaper exports, and other factors created a strong market for used newsprint, corrugated containers, and even mixed paper in 1973. By the end of 1973 prices for wastepaper were at historically high levels. Forecasts by the American Paper Institute predict a 7-percent increase in domestic consumption of old newspaper from the beginning of 1974 through 1975—a steady, but not dramatic growth. However, exports of old newspaper are expected by most observers to increase, and several paper companies are reportedly very interested in building mills to make newsprint from old newspapers. The question of supply of old newspaper seems to be their major deterrent at present.

What is most important for the municipal decision-maker in relation to markets is not to try to predict price fluctuations but to determine the minimum price that he can receive and still have a break-even program and then to negotiate a contract of a year or more duration with that minimum price as a floor. If the price rises above that level, so much the better.

TABLE 18

COMPOSITION OF MUNICIPAL SOLID WASTE, AS DISCARDED, UNITED STATES, 1971 *

Component	Amount (millions of tons)		Percent of total	
Paper		39.1		31.3
News	7.4		6.0	
Corrugated	9.9		8.0	
Mixed	21.6		17.3	
Glass		12.1		9.7
Ferrous metals		10.6		8.5
Nonferrous metals		1.2		.9
Food waste		22.0		17.6
Yard waste		24.1		19.3
Other		15.9		12.7
Total		125.0		100.0

* These waste generation data include wastes generated in household, commercial and business establishments and institutions (schools, hospitals, etc.) and exclude industrial process wastes, agricultural and animal wastes, construction and demolition wastes, mining wastes, abandoned automobiles, ashes, street sweepings, and sewage sludges. Wastes presently recycled are also excluded.

Also, the decision-maker must consider markets on a regional basis since supply lines to market outlets from certain areas may not yet be equipped to process the additional tonnage generated by a separate collection program. It is incumbent upon any city considering resource recovery, therefore, to conduct a market study as the first order of business. In a small city or suburban community this may take the form of a few phone calls to wastepaper dealers or to local manufacturers who utilize wastepaper to manufacture products such as boxboard, chipboard, insulation and roofing materials, and newsprint.

These contacts should be followed by meetings with those dealers and manufacturers who show interest in buying the recovered paper. At these meetings the quality specifications of the buyer, shipping and hauling arrangements, and other requirements which both the city and purchaser must meet can be clarified. Larger cities are advised to conduct a more formal market study and to seriously consider requesting bids from prospective buyers. To proceed further with the project, cities are advised to procure letters of intent from reputable dealers.

If the results of further investigation into the other aspects of a source separation program are deemed to be positive and the project is approved, it is advisable to enter into a formal contract with the buyers. If possible, the contract should first guarantee that the product will be purchased for a specified period of time (this is usually 1 year although some companies are currently offering 5- and 10-year contracts), and, secondly, it should guarantee a minimum or floor price which the city considers reasonable.

Publicity

The success of source separation depends upon citizen awareness, cooperation, and concern. None of these are possible without a vigorous publicity campaign to explain the goals and methods of the program. Such a campaign should begin well in advance of the implementation of the program. Information dissemination techniques such as radio and TV spots, newspaper articles and advertisements, door hangers, and flyers are the usual modes of publicity. The active participation of local environmental groups is an excellent means of stirring public interest. These organizations can be extremely effective through their contacts with schools and other civic organizations. They are usually willing to give speeches, make posters, and conduct door-to-door canvassing at no cost to the city.

Publicity should continue after the program is begun. Occasional flyers inserted in public utility bills as well as weekly or at least monthly newspaper reminders are recommended. One large eastern city includes information on the program with each house title and lease to assure that new arrivals in the community are informed of its efforts in resource recovery.

Householder Impact

Source separation is neither expensive nor time consuming for the householder. In a recent study, 15 families kept detailed records of factors relative to the separation of glass, cans, and newsprint in their homes for a period of 6 weeks. Incidental costs (twine for bundling, water for washing, etc.) were 2 cents per month per family. The average time spent on these activities was about 15 minutes per week. The separate bundling of newspapers took only 2.3 minutes per week and required less than 1 cent per month in out-of-pocket costs. A recent survey of housewives' attitudes on solid waste found that 73 percent of those interviewed felt source separation would be "easy to very easy" for them to carry out.

Scavengers

Due to the increasing value of secondary materials, in many cities unauthorized persons have picked up source-separated materials before the authorized truck arrives. This does not represent a legal problem for municipalities which have chosen to grant an exclusive franchise to a private firm for waste collection. In such municipalities, the sanctions which normally exist to discourage collection by firms other than the licensee may be brought to bear on scavengers. In communities in which such sanctions do not exist, an antiscavenging ordinance should be passed. Legal precedents indicate that in most States it is permissible for municipalities to grant exclusive contracts for the collection of solid waste and to prohibit all but city employees or licensees from collecting it. This, in combination with the municipalities' traditional power to protect the public health and safety, should provide a legal basis for such an ordinance.

The antiscavenging ordinance passed in 1971 in Hempstead, New York, has been used as a prototype in many communities. The ordinance states that all waste placed at the curb becomes the property of the city. Stringent fines are imposed upon scavengers. Strict enforcement, particularly at the beginning of a program, is strongly urged. As much publicity as possible should be given to enforcement efforts in order to discourage potential offenders.

Voluntary versus Mandatory Paper Separation

Most separate collection programs are voluntary in that they *request* citizen support. An increasing number of cities are passing ordinances which *require* separation, however. A recent study of 17 cities found that mandatory programs on the average received cooperation from 60 percent of the population while voluntary programs had a participation rate of 30 percent. These numbers are misleading, however, in that most of the systems have only recently begun.

Other data from the same study indicate that participation rises over time and that as these systems reach the 2- and 3-year level, the relative difference between voluntary and mandatory programs will probably diminish.

Pilot Programs

Most programs are begun with a pilot area and expanded later. This procedure allows the city to gradually adjust to the new system, to experiment with methods which might reduce costs, and to minimize risk. It also allows time for the market to adjust to the new source of supply.

CONCLUSIONS

Recovery of newsprint through source separation and municipal collection on a regular basis is a rapidly growing phenomenon.

The requirements for separate collection of paper have been determined, and some data have been gathered on costs. It is difficult to generalize about costs because of the variation from city to city—a variation due partly to the fact that separate collection is usually fitted into the existing overall collection system. However, the data indicate that separate paper collection can in most cases be accomplished with little or no increase in costs to the city and possibly with a net savings.

Separate collection requires careful planning and administration on the part of the city as well as the cooperation of citizens. The demands placed on citizens are not great, however, and participation to date has been encouraging.

EPA recommends that separate collection of paper be investigated and implemented by any city in which markets are found to exist.

Residential Collection Equipment and Crew Size

When designing or modifying a collection system, equipment selection and crew size determinations should not be made until the policies on level of service have been established (e.g., point of collection and type of storage containers). Based on these policies, preliminary vehicle and crew size selections can be made. The systems recommended below reflect the observations and analyses of Office of Solid Waste Management Programs staff from many studies of different collection methods. Many local factors, such as round-trip time to the disposal site, street widths, housing density, storage container types, labor wage rates, and the amount of waste at each stop, will have an impact on the decisions concerning the selection of vehicle type and crew size (Table 19).

There are many types of collection vehicles available, some of which are designed for specific jobs. All the collection methods described below use a compaction vehicle to reduce haul cost and prevent the litter problems that often occur with open-top trucks.

ALTERNATIVES

Front Loaders

These trucks, which range in size from 21 to 52 cubic yards, collect from bulk containers usually varying in size from 3 to 10 cubic yards. They generally are used to service apartment buildings, large commercial and industrial establishments, and other buildings that generate large volumes of waste.

TABLE 19

RECOMMENDED CREW SIZE AND VEHICLE TYPE FOR RESIDENTIAL SOLID WASTE COLLECTION BY POINT OF COLLECTION AND HOUSING DENSITY

Point of collection	Housing density	
	Single-family homes	Inner city high-density areas
Curbside alley	One man using a side-loading right hand drive vehicle with a low step-in cab	Two men using a side-loading right hand drive vehicle with a low step-in cab or For very heavy waste loads, three men using a rear-loading vehicle with a low step-in cab
Backyard	Two men with tote barrels, using a vehicle with a low step-in cab or Satellite vehicles	Three men with tote barrels, using a rear-loading vehicle with a low step-in cab

Side Loaders

These range in size from 5 to 37 cubic yards. They can collect from bulk containers, but their main use is in collecting from residential and small commercial accounts.

Single-family residential curbside service can be most economically provided by a one-man, side-loading vehicle with right-hand drive, a low step-in cab, and a separate power source for compaction. In this case, collection should be from one side of the street at a time. This system is best suited for areas with fewer items per stop and further distances between stops rather than in areas with a high percentage of multiple-family buildings.

High population density areas with more waste at each stop, very narrow streets, and alley collection may be collected with two-man crews using a right-hand-drive, side-loading vehicle. Both sides of the street or alley are collected at the same time (assuming street width and traffic volume do not present problems).

Rear Loaders

These range in size from 6 to 31 cubic yards, and can collect from bulk containers, but their main use is in collecting from residential and small commercial accounts.

High population density areas with more waste at each stop, very narrow streets, and alley collection may be collected with rear loaders and three-man crews (including the driver, who also collects at heavy stops). Both sides of the street or alley are collected at the same time (assuming street width and traffic volume do not present problems).

Backyard service in high population density areas containing closely spaced single-family dwellings or a predominance of multiple-family dwellings with short street-to-storage distances should be collected with a three-man crew (including the driver who also collects) using tote barrels and rear-loading vehicles.

Satellite Vehicles

Medium and low density single-family residential backyard service can be economically provided by satellite vehicles. These vehicles are usually driven to the area where they will be used each day or they may be towed behind the "mother" truck on a trailer. They may be stored in decentralized garages. The small, usually noncompacting, three- or four-wheeled vehicle is driven up the driveway as close as possible to the waste. When filled, the vehicle is returned to a mother truck for emptying. The selection of a satellite vehicle system rather than tote barrels depends on the accessibility of the waste storage point to the vehicle, the distance from street to storage, and the distance between services. Another consideration is the availability of a mother truck with a hopper compatible to the hopper of the satellite vehicle when dumping.

Specialized Collection Vehicles

In addition to the more traditional collection truck types, there are many different specialized vehicles used today. Some have mechanical arms, such as the "Son of Godzilla" used in Scottsdale, Arizona, and the Mechanical Bag Retriever* used in Bellaire, Texas. Some communities use container trains, which are basically very primitive and inefficient. Still other methods involve the use of multifamily bulk bins to collect residential waste; these methods include the system of alley collection from bulk metal bins used in Odessa, Texas, the "Son of Godzilla," and the barrel tipper for alley collection used in Tolleson, Arizona. In Covina, California, a one-man mechanical bag collector, the "jumping bean," which shows promise for specific applications, is being developed. The use of these vehicles under the conditions for which they were designed can substantially reduce collection costs. Some require large initial capital investment while others require extra citizen cooperation.

Roll-off containers and roll-off trucks which accommodate payloads of 12 to 47 cubic yards serve large waste generators. Lift-and-carry systems which handle 3- to 15-cubic-yard payloads are generally used for specialized wastes such as semiliquid, liquid, or hazardous wastes. These vehicles have a high operating cost since the payload is limited by the fact that only one box can be serviced by a truck. Front loaders or the larger roll-off systems are more economical.

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* Mention of commercial products or organizations does not constitute endorsement or recommendation for use by the U.S. Government.

OTHER CONSIDERATIONS

Many additional factors must be considered before the final vehicle and crew size decision is made. For example, crew size selection will be affected by the amount of waste per stop, haul time to the unloading point, wage rates, and labor preference and persuasion. Preliminary results from an OSWMP safety study show that a large percentage of accidents occurring during collection are caused by the interaction of crew members, and this may be a consideration in favor of smaller crews. In high population density areas, the larger quantity of waste at a given stop makes larger trucks with three-man crews economically competitive with smaller crew sizes. Where crew size reduction is a goal, labor's resistance may pose a serious obstacle. Increased wages and labor force reduction through attrition and assignment to other city departments can help smooth any transition to smaller crews.

Vehicle selection is affected by such local constraints as haul time to the processing or disposal site, street or alley width and intersection size, types and amounts of waste (hopper size requirements), and highway load limitations (number of axles required). Haul time is important because time on the route is reduced by the amount of time spent driving to the unloading site. Haul time can be reduced by either reducing the number of trips to the unloading site through increased vehicle capacity or by locating an unloading site closer to the collection area, i.e., set up a transfer station.

Vehicle size depends partly on street width since narrow streets can preclude large vehicles with wider turning radii. If this is not a problem and a long haul time suggests a larger vehicle, tandem axles may be required because of highway load limits. Tandem axles have several disadvantages that can increase costs. The vehicles themselves are substantially more costly. They are not designed for the turning and maneuvering most collection vehicles must perform. Therefore, unless these trucks are run in a straight line down the street, their maintenance cost will increase. In addition, they cause more wear on the roads and are more difficult to drive. Overall, these disadvantages may be greatly outweighed by reduced hauling costs, but they must be considered. As a general rule of thumb, when lengthy haul times are not a problem and street widths permit it, a 20-cubic-yard vehicle should be selected. This vehicle size provides the maximum amount of flexibility to handle increasing waste loads and changing disposal site locations without the problems encountered with tandem axle vehicles.

Other considerations before purchasing a vehicle include overhead clearances under bridges and at the garage, the availability of parts, and warranty service. Also, decisions on such items as transmission and fuel type need to be made. Automatic transmissions are initially more expensive, but over the life of the vehicle the cost of clutch replacement exceeds the initial differential. Also, automatic transmissions are easier to drive and safer in hilly areas.

Currently diesel engines are initially more expensive than gasoline-fired engines, but over the life of the engine the operating and fuel cost savings of the diesel engine exceeds the initial cost difference. Diesel engines also produce less air pollution. One drawback of diesels is that they may be harder to start in cold weather.

Chassis and body replacement policies should be included in long-term purchase plans. Chassis replacement depends upon engine operating hours, which is related to mileage. However, most communities prefer to think in terms of years. As a general rule, the chassis should be replaced every 3–4 years and bodies every 6–8 years. Need for replacement should be calculated on an individual basis, being sure to take into account the cost of downtime for the older vehicles.

One additional consideration before purchase is safety. If the safety standards developed by the American National Standards Institute for rear-loading and side-loading collection vehicles are implemented as proposed, all vehicles manufactured after January 1, 1976, will be required to meet rigid safety standards. It is advisable to include in bid specifications the requirement that once these standards are adopted any vehicle delivered must meet them.

The costs related to collection vehicles are described in greater detail below.

Vehicle Costs

The costs are generally divided into the following categories:

- I. Vehicle capital cost (fixed cost)
  - A. Chassis
  - B. Packer body
  - C. Volume and type of purchase
- II. Operating cost (variable cost)
  - A. Consumables (gas, oil, tires)
  - B. Maintenance and repair (labor and parts)
- III. Overhead cost (fixed cost)
  - A. Insurance
  - B. Registration, license, and permit fees
  - C. Garage (rent and utilities)

For equipment replacement analysis, the cost of downtime from breakdowns should be included, with the fixed and variable costs listed. The following discussion covers vehicle capital and operating costs.

Vehicle capital cost is based primarily on the following factors:

- A. Chassis
  - 1. Make (Ford, Dodge, GMC, International, White, etc.)
  - 2. Horsepower
  - 3. Fuel type (diesel vs. gas)
  - 4. Number of axles
  - 5. Other options (automatic vs. standard transmission, power vs. regular steering, power takeoff vs. auxiliary engine, right-hand drive)
- B. Packer body
  - 1. Manufacturer
  - 2. Type (front, rear, or side loader)
  - 3. Capacity (cu yd)
  - 4. Compaction capability (reinforcement and power)
- C. Volume and type of purchase (number of trucks, bid basis)

There are at least 24 manufacturers of solid waste packer trucks: 13 make rear loaders, 13 make side loaders, and 11 make front loaders. There are at least 14 manufacturers of chassis for packer trucks. Considerable ranges are to be found in the prices (Table 20).

Operating costs are based on the following factors:

- A. Consumables: Gas, oil, and tire costs are functions of equipment usage.
  - 1. Gas and oil consumption is more closely related to hours of use than miles. It is affected also by point of collection (backyard vs. curbside), type of collection (residential, commercial, rural), and haul distance to the disposal site.

TABLE 20

TYPICAL RANGES IN PACKER TRUCK COSTS (INCLUDING CHASSIS), 1972

Standard sizes (cu yd)	Costs ($)
Rear loaders:	
6–31	7,000–35,000
20 *	18,700–24,000
Side loaders:	
5–37	10,000–33,000
Front loaders:	
24–42	24,400–40,000
Roll-off:	
13½–45½	8,100–30,000

* The cost figures for the 20-cu-yd rear loader are broken out separately because of the prevalence of this vehicle size.

2. Tire life is closely related to the vehicle's disposal point. The chance for punctures is greatly increased if the disposal point is at a land disposal site rather than a transfer station or other concrete pad discharge point. Other major factors affecting tire life are total miles driven, condition of roads, and air pressure maintenance.

B. Maintenance and repair costs are related to the effectiveness of the preventive maintenance program, how carefully the packers are driven, and reliability and sturdiness of the equipment (initial cost).

Fuel consumption rates for residential collection are shown below. These figures are based on data for 1 month in 1973, on 24 diesel and 20 gas packers from 11 communities using the EPA Data Acquisition and Analysis Program (DAAP).

	Hours per gallon
Backyard service	
Diesel	0.74
Gasoline	.58
Curbside service	
Diesel	.47
Gasoline	.36

Data on 73 20-cubic-yard gas vehicles with an average age of 3.3 years from a southern community reveal the following annual costs per truck:

Fuel (at $0.214/gal)	$1,296
Oil (engine and hydraulic)	144
Maintenance and repair	
Parts	1,752
Labor	1,956
Total	5,148

In the DAAP study, annual fuel costs for the 44 packers were $300–$1,600 at $0.17 per gallon or $700–$3,800 at $0.40 per gallon. Maintenance and repair costs ranged from $313–$5,725 per year, but averaged $1,901. Oil (engine and hydraulic) averaged $390 per year for the four trucks for which this was recorded. Thus, the figures in the table appear to be representative, except that the maintenance and repair costs appear to be unusually high.

Typical annual costs to operate a 20-cubic-yard, rear-loading diesel packer for curbside residential pickup, averaging 7 hours per operating day, are:

Depreciation (5-year, straight line)	$4,800
Fuel (at $0.20/gal)	775
Oil (engine and hydraulic)	160
Tires	840
Maintenance and repair	
Parts	800
Labor	1,200
Insurance and fees	1,200
Total	7,875

CONCLUSIONS

In summary, the determination of the optimum combination of equipment type and crew size is very complex. There are many dependent variables which impact on the decision. Furthermore, the problem is a dynamic one in the sense that changes in system parameters such as waste generation, traffic congestion, or haul distance may mean there is a new optimum combination. Collection systems must continually review the influencing factors in order to be sure that their current decisions on equipment and crew size are indeed optimal.

Personnel Incentive Systems

In many communities, personnel incentive systems have increased productivity in solid waste collection while increasing employee morale.

ALTERNATIVES

There are three basic workload systems: (1) the flat 8-hour day, (2) a task incentive system in which a set task is assigned to each collection crew or group of crews and, when the task is completed, the crews are permitted to go home, and (3) a monetary incentive system in which each crew or group of crews have a standard task and for any work beyond that they are paid an extra amount.

ADVANTAGES AND DISADVANTAGES

Flat 8-Hour Day

With this system if the crew members finish their task early they must remain on thejob until their 8 hours are up. Conversely, if they don't finish in 8 hours they receive overtime pay. The result is that there is no real incentive to "hustle" on the routes.

Task Incentive

This system allows the men to set their own work speed, skip breaks and lunch, and go home early when their routes are completed, provided that no crew has fal'en behind during the day due to breakdowns or other unusual delays. In this case, the first crews done are asked to pitch in and help.

When the task is assigned to a group of truck-crews (typically all trucks under one foreman), no crew is permitted to go home until the entire task is completed or "covered." This combined task system is often referred to as the reservoir system since on a given day all crews end up in a central or reservoir area. With the reservoir system all crews work a similar number of hours, and peer pressures for all crews to set a good pace increase productivity.

The advantage of task incentive systems is that they encourage crews to work faster, thereby increasing productivity. Also, task systems tend to result in a more satisfied work force as long as the task is perceived as a reasonable day's work.

The primary disadvantage of a task system is that, by working fast to complete the route, there is the potential for a reduction in the quality of service. Additional supervision may also be required to insure that each house receives service and that the solid waste and cans are handled properly.

Monetary Incentive

There are several forms of monetary incentive. One method is to give additional pay to crews which, having finished their own tasks, assist other crews which have fallen behind their normal pace because of breakdowns, absenteeism, or other unusual problems. Another wage incentive system takes the form of payments for increased productivity, decreased overtime, decreased costs, or increased profits. In a private firm this may be a profit-sharing system whereby the crews are paid a part of the profits or increased profits in a specific period. In a public agency incentive pay could be a share of cost savings. In one such system, the city, Detroit, shares 50 percent of the cost savings from increased productivity with the crews on a scale graduated according to which crews contributed the most toward the savings, as determined by a specific formula. The city of Detroit has reported substantial savings since this system was implemented in July 1973. Another way to do this with less administrative expense while encouraging peer pressures is to reward all the crews equally with a share of the savings. For inefficient systems, sharing of cost savings is certainly one approach worth considering.

The disadvantage of monetary incentive programs, as with the task incentive, is the danger that work quality will go down as workers hurry to complete their jobs.

OTHER CONSIDERATIONS

Regardless of whether or not an incentive system is used, it is important to have a standard for a fair day's work. That is, it is important to determine a fair day's work for each route in terms of the number of stops per day to be collected. Clearly, all routes should not have the same number of stops since housing density, road width, street traffic, distance from disposal site, the presence of hills or alleys, and other factors introduce variability among routes. A fair day's work can be determined for each route through time-and-motion studies, and tasks can be negotiated with the union or the workers. (Refer to Appendix A, "Residential Collection Management Tools" for a more detailed explanation of a "fair day's work.")

CONCLUSIONS

Incentive systems will generally result in higher productivity, lower costs, and a more satisfied labor force.

conservation, environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

Residential Solid Waste Collection in Rural Areas

conservation, environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

The collection methods used in urban areas have little applicability to rural areas because of the much greater distance between stops. However, there are techniques available for rural collection, and local officials must decide which of these best suits their situation.

ALTERNATIVES

Four techniques can be used for solid waste management in rural areas. These are: disposal of waste on one's own property, direct haul by the resident to the disposal site, the use of centrally located bulk containers, and house-to-house collection of solid wastes.

Each of these systems requires citizen cooperation. Some States empower local authorities to require mandatory solid waste collection throughout their jurisdiction. In these areas, the governing agencies must provide adequate service, and residents must accept and pay for the service. Exceptions are allowed where the householder can prove that he is privately disposing of his waste in a satisfactory manner, usually by burying the waste on his property in a location approved by the governing agency.

There are three requisites for instituting mandatory collection. State enabling legislation must exist to allow local government agencies to enact ordinances requiring mandatory collection; an economically feasible system must be available to provide collection service to all residents; and governing agencies must be available to operate the system. Legal, political, or economic reasons often preclude mandatory solid waste collection in rural areas even though it might be desirable. The logical alternative to a mandatory system is a voluntary system. A mandatory system will theoretically collect 100 percent of the residential solid waste generated within a political jurisdiction, whereas a voluntary system may collect much less. The real crux of the matter is whether the resident is required to pay for solid waste collection service or not. Voluntary acceptance of charges for solid waste collection should not be expected from a large percentage of the population.

Although data on collection costs are not generally available for rural systems, a total operating cost of $7 to $15 per ton can be anticipated for the average bulk container collection system.

ADVANTAGES AND DISADVANTAGES

Disposal by Residents

The simplest method is the direct disposal of wastes on one's own property. It provides the least service at the least expense to the rural government. However, it is the system that is the most difficult to monitor and control. It also encourages roadside dumping as well as open burning, which are unacceptable practices. In order to be successful, an extensive educational campaign is needed to ensure the proper disposal of wastes.

Hauling by Residents to Landfills

The direct haul of wastes by the resident to a central sanitary landfill eliminates some of the problems associated with disposal of wastes on one's own property. The distance to the landfill may discourage some residents from using it regularly, however. Roadside littering as well as traffic at the disposal site may also create problems.

Bulk Container System

In a bulk storage container system, a number of containers, enough to serve the needs of the rural population, are strategically located along highways or roads easily traversed by a collection vehicle. The individual resident is required to transport his waste to the bulk containers, which are serviced by a suitable collection vehicle; the collected wastes are transported to a central sanitary landfill or processing facility.

There are two different types of bulk storage container systems. In one system, bulk containers are boxes with lids or doors ranging in size from 3 to 8 cubic yards and serviced by emptying into a larger collection vehicle. The other type of bulk container system uses large open boxes with a capacity of approximately 20 to 40 cubic yards. These large boxes are not emptied but instead are replaced regularly by empty boxes, with the full boxes being taken directly to the processing or disposal site.

There are three basic types of bulk bin collection vehicles—front-loading, rear-loading, and side-loading, each with its own characteristics and capabilities (Table 21).

In calculating the bulk container capacity required for an area, it may be useful to consider that the average number of persons served per cubic yard of bulk container space, based on figures from selected areas, is 9.8 (Table 22). However, the ratio of persons per cubic yard varies widely depending on local conditions. To determine the number of containers that can be emptied into a collection truck, the following estimates can be used. For loose solid waste, a density in the container of 75 to 150 pounds per cubic yard can be expected. A density in the collection vehicle of 450 to 900 pounds per cubic yard of compacted waste can be expected. Data on the density that can be achieved by any specific type of collection truck can be obtained from a list of specifications or dealer.

Site locations should be chosen according to commonsense criteria. For example, con-

TABLE 21

CHARACTERISTICS OF RURAL BULK BIN COLLECTION SYSTEMS BY TYPE OF VEHICLE USED *

Item	Vehicle type		
	Front-loading vehicle	Rear-loading vehicle	Side-loading vehicle
Crew size	One driver-collector	One driver, one to three collectors	One driver, one or two collectors
Typical container servicing time	1 to 2 min	2 to 6 min (includes some litter cleanup)	1 to 3 min (includes some litter cleanup)
Container site development	Requires pull-off area from main road, with gravel or paved surface common	Requires area in which to back up to container; gravel or paved surface is common	If users and collection vehicle can stop safely along road, site needs to be only slightly larger than containers; otherwise pull-off area is common with gravel or paved surface
Container sizes	0.8 to 8 cu m (1 to 10 cu yd)	0.8 to 4.5 cu m (1 to 6 cu yd)	0.8 to 3.1 cu m (1 to 4 cu yd)
Site maintenance	Usually a special crew cleans sites periodically	Collection crew cleans up as containers are emptied	Collection crew cleans up as containers are emptied
Typical packer body sizes	15.3 to 30.2 cu m (20 to 40 cu yd)	12 to 22.7 cu m (16 to 30 cu yd)	9.9 to 24.5 cu m (13 to 32 cu yd)
Types of wastes collected	Any wastes that will fit inside container	Any wastes that will fit into rear-loading hopper	Any waste that can be placed through the side doors
Vehicle flexibility	Can service only front-loading containers	Can service both rear-loading containers and house-to-house collection	Can service both side-loading containers and house-to-house collection

* Source: GOLDBERG, T. Improving rural solid waste management practices. Environmental Protection Agency Publication No. SW-107. Washington, U.S. Government Printing Office, 1973. 83 p.

tainers should be located so that they will be on the way for users going to town, church, or school. Containers should be located with regard to where the people are. The maximum distance of a container from any user should not be over 3 to 5 miles. If containers are placed near existing dumps, they are more apt to be successful because of the strength of habit of the users.

There are several major advantages to this type of system. The first is that a collection system is provided where usually none had existed before. Promiscuous dumping and community dumps are generally reduced. Public acceptability is usually high. Development costs of the individual container sites are relatively low. The sites can be located close to the users, and population and waste-generation changes can be easily adapted to by changing the number and locations of the containers. A centralized sanitary landfill that incorporates economies of scale can be used. Servicing of commercial and industrial establishments and recreational areas can be easily done. Not the least advantage is that the costs of this kind of system, once established, can be predicted to a reliable degree.

As with any system, there are also disadvantages. Two disadvantages accompany any system change in a solid waste disposal system. First, the initial capital investment cost may be quite high. Truck costs start at approximately $30,000 and smaller containers at $200 each. Second, the initiation of a new program may cause existing collection systems, whether private or municipal, to immediately decrease service in the area.

The system can be financed by user charges, but only with difficulty. As with any unattended site, vandalism may occur and unsanitary conditions may develop un-

TABLE 22

EXAMPLES OF RURAL SOLID WASTE COLLECTION EQUIPMENT SYSTEMS

Location	Estimated population	Number of containers	Size of containers (cu yd)	Collections per week	Number of persons per cu yd storage	Number of trucks	Size of trucks (cu yd)	Initial capital cost
Baldwin Co., Ala.	47,000	*		1		14	16–23	$240,000 †
Chilton Co., Ala.	17,000	91	4	3	16	2	30	68,000
Choctaw Co., Ala.	14,000	*		1		3	20	48,000
Coffee Co., Ala.	14,000	170	4	1–2	14	1	30	62,700
Macon Co., Ala.	13,800	137	4	1–2	17	1	30	55,900
Madison Co., Ala.	40,000	*		1		9	23	160,000
Tuscaloosa Co., Ala.	30,000	335	5, 6	2	7	5	30	310,000
Evans Co., Ga.	7,290	10 70	3 4	2–3	9	2	23	60,695
Grady Co., Ga.	10,000	126	4	2	10	1	20	49,787
Screven Co., Ga.	9,500	164	4	2	7	1	25	66,000
Benewah Co., Idaho	3,680	14	12 ‡	2	11	1	20	†
Bonner Co., Idaho	3,000	39	10	2	4	1	20	38,400 †
Boundary Co., Idaho	2,300	17	10	2	7	1	20	17,540 †
Kootenai Co., Idaho	2,250	10 20	10 ‡ 12 ‡	2	3	1 1 1	10 16 20	50,900 †
Shoshone Co., Idaho	1,016	11 12	4 ‡ 12 ‡	1–2	4	1	16 20	†
De Soto Co., Miss.	50,000	72 78 7	6 4 30	2	26	1 1 1	30 roll-off roll-off	†
Humphreys Co., Tenn.	8,796	134 23	6 8	2	4	2	31	105,465
Jefferson Co., Tenn.	17,014	128 17	4 6	2	14	1	30	68,310
Polk Co., Texas	9,500	110 60	4 3	3	5	2	30	93,086

* Mailbox system.
† Contracted.
‡ Hand unload.

less the sites are properly maintained. Users of the system must carry their own waste to the containers, which may be a hardship for those without means of transportation. To work well, this kind of service must supply a substantial number of containers at accessible sites. The amount of waste picked up at each container may be unpredictable and cause scheduling problems, at least until new sites or more containers are supplied. Finally, if this kind of rural service is used near municipalities, the containers may be used by town residents if there is inadequate town service.

Mailbox System

In this house-to-house collection system, a collection vehicle travels rural postal delivery routes collecting waste that has been placed next to mailboxes.

This system assumes: (1) if a mail truck can travel a route, a collection vehicle can travel the same route; (2) over the years, the postal system has probably developed the most efficient routes for traveling the region; (3) since all mailboxes on a rural route are required to be accessible to a driver and on the same side of the road, containers will have to be picked up from only one side of the road. For households that do not have mailboxes on the postal routes, the customer and collection agency must agree on a mutually acceptable collection site. A house-to-house system, such as the mailbox, requires that collection days and times be designated so that residents know when to set out their waste. Recently the mailbox system has become very popular in Alabama, where 67 percent of the unincorporated population is now serviced by this method in comparison to 23 percent serviced by bulk containers.

The advantages to this type of system are that it collects the largest percentage of generated household waste of any system, it permits a high level of scheduled service to the rural resident and business establishments, and it provides a system for which user charges can be established.

The mailbox system does have some disadvantages in that homeowners must cooperate in setting out containers on the roadside and following service schedules. Litter problems may occur if bags are torn or if containers are upset along the road. Also, the system may be time consuming and costly to utilize in isolated areas.

In considering the use of a house-to-house system for rural solid waste collection, numerous factors must be evaluated in terms of the funds available, such as frequency of collection, type of storage container, kind and size of equipment, and crew size. Most critical is the expected level of participation by residents.

CONCLUSIONS

Two of the four methods of rural waste management rely heavily on the residents themselves, since they must either dispose of the waste on their own property or haul it to a sanitary landfill.

If a bulk storage container system or house-to-house system is proposed for a given rural area, a thorough investigation must be undertaken to determine what the population is willing to support. In order to rationally select between system alternatives, there must be an understanding of the level of service desired as well as the cost for each system.

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criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

TRANSFER STATIONS AND TRANSPORTATION TO DISPOSAL SITES

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

Transfer Stations and Transportation to Disposal Sites

conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

In many areas of the country, sanitary landfills are distant from urban areas because of the shortage of suitable land nearby. The result is that many man-hours can be spent in hauling solid waste from the collection zone to the disposal area. This situation can be alleviated by using a transfer station.

A transfer station is a facility where the solid waste from several relatively small vehicles is placed into one relatively large vehicle before being hauled to the disposal site. The small vehicles can be private automobiles, pick up trucks, or, more commonly, collection vehicles. The large vehicles can be barges, railcars, or trucks.

Although a transfer operation offers potential savings, it requires an extra materials-handling step and the construction of a transfer facility. The associated costs must be recovered or money will be lost in the transfer operation. The costs that are incurred are as follows:

1. The capital expenditures for land, structures, and equipment
2. The costs for labor, utilities, maintenance, operation, and overhead at the transfer plants
3. The costs for labor, operation, maintenance, and overhead incurred in the bulk hauling to the disposal site.

Costs are saved with the utilization of a transfer operation because:

1. The nonproductive time of collectors is cut since they no longer ride to and from the disposal site; it may be possible to reduce the number of collection crews needed because of increased productive collection time.
2. Any reduction in mileage traveled by the collection trucks results in a savings in operating costs.

ALTERNATIVES

Barging

New York City and Seattle are among the few cities now using barges to haul waste to disposal sites. Because of lack of interest in this type of transport, barge haul does not seem to have much potential for development in the near future except in very specialized applications.

Rail Haul

Rail haul has generated considerable interest in the past several years, but to date no city has solved all the political problems associated with the concept. Rail haul does, however, have the potential to become a major factor in the national solid waste management system. Most of the proposed rail haul projects designate strip mines as the disposal site. When this is the case, two environmental problems can be solved: the proper disposal of waste materials and the reclamation of the strip-mined areas.

Truck Transport

The popularity of truck transfer systems has led to the development of equipment specifically suited to this purpose. Early transfer station operations relied completely on equipment built by various manufacturers to specifications of the operating authority. In the 1960's, solid waste equipment manufacturers developed specialized processing and hauling equipment. At the present time those interested in a truck transfer operation

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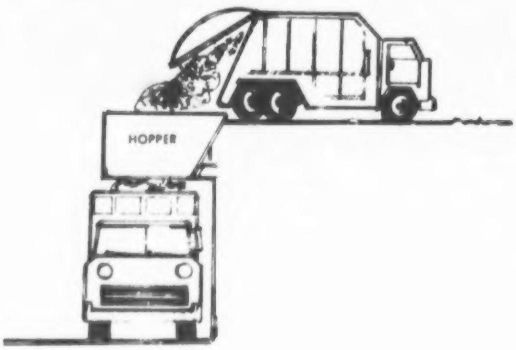
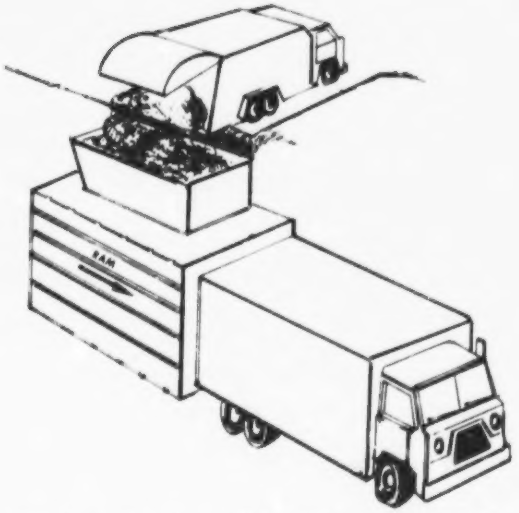
have the option of either designing their own system and writing specifications for desired equipment or buying specialized equipment from the manufacturers and designing the system around it.

Two basic types of transfer systems have developed as a result of these options. The first is the direct-dump system where a collection truck dumps by gravity into a large open-top trailer. The trailer is located under a funnel-shaped hopper to prevent spillage, and a backhoe is usually used to compact and distribute the load after it has been placed in the trailer. A variation of this system utilizes a dumping pit where a crawler tractor crushes and compacts the waste before pushing it into the trailer via the hopper. Because of the densities achieved with the crawler tractors, a backhoe is usually required for load distribution only. The compaction pit system is used primarily in high-volume transfer stations because of the expense of incorporating the extra equipment, whereas the direct-dump system has been used in both small and large installations. All direct-dump systems are characterized by the fact that open-top trailers are used and the equipment employed is usually not specially predesigned for solid waste transfer. Some type of cable system is usually employed to pull the loads out of the rear of the trailer at the disposal site.

The second basic transfer system utilizes hydraulic pressure to achieve horizontal compaction of the waste within the trailer. Two methods have been used to achieve compaction. Both are characterized by the use of enclosed reinforced-steel trailers specifically manufactured for solid waste transfer. The first compaction method is partially a direct-dump operation in that waste is dumped directly into the trailer, near the front. A hydraulic-powered bulkhead traverses the length of the trailer and compacts the waste against the rear doors. The entire compaction process is self-contained within the trailer body. At the disposal site, the bulkhead pushes the load out through the rear doors.





The second compaction method requires the use of a stationary compactor. The transfer vehicle is backed up and securely fastened to the compactor. Waste is fed by gravity into the compactor chamber from an overhead hopper. The compaction ram forces the waste forward into the trailer through the rear in horizontal reciprocating cycles. This trailer is also equipped with a hydraulic-powered bulkhead which traverses the length of the trailer for unloading at the disposal site. Either compaction method can easily produce maximum legal payloads.

COSTS

Barging

There are no representative costs to be reported from this type of transport.

Rail Haul

Because of a lack of any sustained operating experience in the rail haul of solid waste, it is impossible to provide accurate cost figures. However, preliminary costs on two proposed operations can be cited. For the pend-ing Atlanta rail haul operation, Southern Railroad has contracted with Atlanta to transport and dispose of 500 tons per day of baled wastes for $3.75 per ton. The haul distance is about 100 miles. Atlanta will handle the transfer, processing, and loading operations at a projected cost of an additional $3.25 per ton. The city of Philadelphia recently considered rail hauling 1,000 tons of solid waste per day a distance of 350 miles to an abandoned strip mine. Under this plan, the wastes would be placed unprocessed in large containers which would be loaded onto flat cars for shipment. The total estimated cost is $13.23 per ton.

Truck Transport

For truck transfer operations, the best method of reporting the cost is to use two categories. The first category is the cost of owning and operating the transfer facility. Data collected between 1968 and 1971 show costs ranged from $1.25 to $2.25 per ton. The second category is the haul costs. These costs ranged from $1.50 to $2.50 per ton. From the facilities that do not report costs in these categories, total costs ranging from $2.25 to $4.50 per ton were reported.

In general, anyone considering a transfer operation must determine if the savings will exceed the costs. The primary variable is the distance to the disposal site. Attempting to apply a rule of thumb (such as "A 10-mile haul distance justifies transfer") to this determination is unrealistic and mere guesswork unless a study is made of local conditions. A decisive distance in one area may be totally insignificant in another. Factors such as wage rates, type of access roads, collection truck capacity, and size of collection crews (one-man, two-man, etc.) can change the break-even distance considerably.

Although distance to the disposal site is important in comparing direct haul with transfer and haul, a more realistic criterion is the time necessary to travel the distance since the major item in total haul cost is labor, which is directly related to time and not distance. Variables such as routes taken, traffic conditions, and speed limits could result in a time of 15 minutes to cover 10 miles in one area and an hour in another area.

For these reasons, the usual unit of comparison, the cost per ton per mile, should be replaced by the more realistic unit of cost per ton per minute when making transfer station calculations (Figure 4). In general, a larger vehicle has a greater payload and a lower cost per ton/minute (or mile). Thus the 20-ton transfer rig has a flatter haul cost curve than does a 5-ton collection packer truck, but the haul cost for the transfer rig must be superimposed on the cost of the transfer station.

ADVANTAGES

Even though a transfer operation requires an extra materials-handling step and the construction of a facility, its use may reduce the system's total costs.

A transfer station offers a convenient, close-in site for residents to deposit their waste. It may be a good location for a resource recovery facility. Some solid waste equipment manufacturers now offer transfer systems that can be converted to resource recovery by adding components to the basic facility.

DISADVANTAGES

The major disadvantage of setting up a transfer station is the problem of public acceptance, which is common to almost all solid waste management facilities. While many people will recognize the need for a facility, very few will allow it to be built near their homes.

OTHER CONSIDERATIONS

The economic justification of a transfer system requires a reduction in the number of collection crews needed in an established collection system. This will bring about a surplus of men and equipment within the operating agency, as well as a need to redistribute the workload among the remaining crews.

In a system using a transfer station, the opening or closing of a particular disposal site will not affect the collection routes. This is true because a transfer system makes the collection operation independent of the disposal facility.

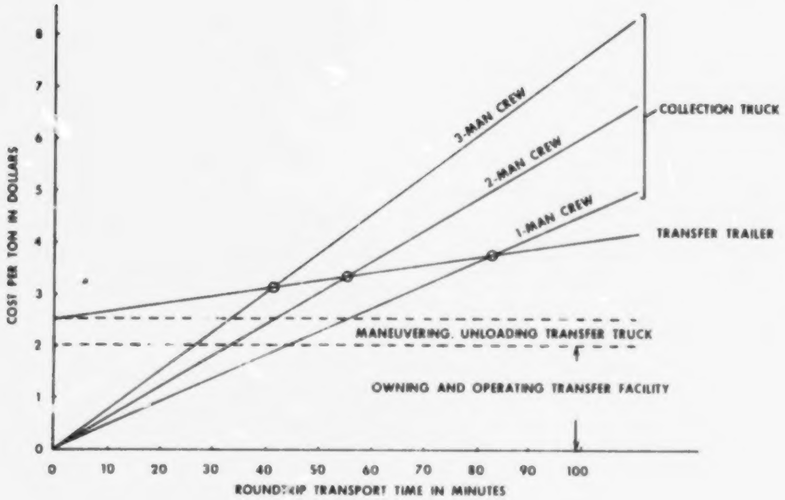


Figure 4. This represents a typical method for evaluating costs of transporting waste to the disposal site. For the transfer rig, the haul cost is imposed on the cost of transfer operations. In this illustration, a cost for transfer of $2.50 per ton has been assumed. Ultimately the curve for the transfer rig plus the transfer station will intercept the steeper curve for the collection packer truck. The point of interception, when projected downward, will show the roundtrip time at which a transfer operation is justified. The data used to derive this graph is presented below, solely for the purpose of demonstrating the method. Source: Greco, J. R. Transfer station feasibility is measured against direct haul. *Solid Wastes Management*, 17(4):13, Apr. 1974.)

Transportation costs per vehicle	Direct haul	Transfer
Time-based costs per year		
Vehicle amortization[*]	$ 5,260	$ 9,468
Driver's salary, fringe benefits[†]	10,625	12,500
Collector's salary, fringe benefits[†]	9,375	0
Vehicle insurance, licenses, taxes	1,500	2,500
Subtotal	26,760	24,468
Subtotal per minute[‡]	$ 0.214	$ 0.196
Mileage-based costs per mile		
Fuel,[§] oil, tires	0.080	0.150
Maintenance and repair	0.050	0.050
Subtotal	0.130	0.200
Subtotal per minute[¶]	0.087	0.107
Total per minute	0.301	0.303
Total per ton per minute	0.060	0.015
Estimated cost per ton for owning and operating transfer facility	0	2.00
Estimated cost per ton for maneuvering and unloading transfer vehicle	0	0.50

[*] Diesel compactor truck ($25,000) with a 5-ton payload capacity and diesel tractor trailer ($45,000) with 20-ton payload capacity amortized over 6 years at 8 percent per annum.

[†] Fringe benefits approximated as 25 percent of salaries (collection truck driver, $8,500; collector, $7,500; transfer trailer driver, $10,000).

[‡] Assumed 5-day work week, 8-hour work day.

[§] Fuel costs dependent upon price (e.g., 30¢ per gallon) and consumption (e.g., 6 miles per gallon).

[¶] Roundtrip transport, 40 miles roundtrip transport time, 60 minutes for collection truck, 75 minutes for transfer trailer.

CONCLUSIONS

Transfer systems offer an economical alternative to direct haul of solid waste by the collection crew to a distant disposal site.

No rule of thumb exists to determine when to use a transfer system. Each case should be evaluated individually based on distances to feasible disposal sites, local labor costs, and other factors mentioned herein. It is essential, however, that systems utilize transfer whenever applicable to reduce nonproductive use of collection labor and equipment.

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criteria: cost, institutional factors, resource conservation, environmental effects

decisions: collection, transport, processing, disposal

PROCESSING

decisions: collection, transport, processing, disposal

criteria: cost, institutional factors, resource conservation, environmental effects

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation

Baling

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation

environmental effects decisions collection disposal processing transport environment

Baling is a method of reducing solid waste volume which has the potential to achieve cost savings when transfer and long haul are necessary prior to disposal. The decision to be made is how well baling and the operation of a balefill compete with nonbaling and conventional landfilling on an economic and environmental basis for the particular community. Also, the different forms of baling must be compared with each other.

ALTERNATIVES

There are, at present, two main types of balers. One type, the converted scrap baler, achieves such high densities that no baling wire is needed. Raw refuse is baled without any preprocessing. This has been demonstrated in St. Paul, Minnesota.

The second type is the converted hay baler, which requires baling straps even though high densities are achieved. Waste must be shredded prior to baling. This process has been demonstrated in San Diego.

These two baling processes should be compared with the operation of a transfer station and hauling "loose" refuse to a conventional disposal site.

COSTS

When these three alternatives are compared in terms of costs, conventional disposal with transfer comes out as the costliest at $9.25 per ton (Table 23). The San Diego baling process is costlier than the St. Paul process ($8.62 versus $7.01-$7.38). These baling costs are for pilot plants operating at

TABLE 23

COMPARATIVE ECONOMICS OF ST. PAUL BALER, SAN DIEGO BALER, AND CONVENTIONAL DISPOSAL, INCLUDING TRANSFER

Item	St. Paul baler and transfer	San Diego baler and transfer	Conventional disposal and transfer
Densities in place (lbs per cu yd)	1,500-2,000	2,000	800-1,200
Costs (per ton) *			
Land acquisition †	$0.90-1.35	$0.90	$1.80
Landfill operation	1.03	.28	3.20
Baler acquisition and operation	3.78 ‡	6.22 §	—
Conventional transfer station operation	—	—	2.00
Transportation to fill	1.22	1.22 •	2.25
Total cost	$7.01-7.38	$8.62	$9.25

* All costs are in 1973 figures.

† Assumes a site 100 yd × 100 yd × 10 yd deep acquired at $1 per sq yd, or $10,000 for the site.

‡ Very conservative (high) figure in that the plant is operating at 65 percent utilization and with a 137 second-cycle machine (90-second-cycle machine is the current production model).

§ Very conservative (high) figure in that plant is currently operating at 67 percent utilization.

• No data available—figure for St. Paul is used on the basis of similar densities.

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two-thirds capacity; costs are expected to be lower for full-scale operations. Moreover, the current model of the St. Paul baler is being superseded by a higher speed model that will further reduce costs (Table 24 and Figure 5).

ADVANTAGES

- Nearly doubles the life of the land disposal site and therefore reduces the number of times the city government must go through the politically difficult process of acquiring a new disposal site
- Cheaper than transferring, transporting, and landfilling nonbaled waste
- Permits immediate use of the disposal site upon completion (minimal settling); may be environmentally superior to conventional disposal site operations
- Balefill sites are clearly superior esthetically to conventional sanitary landfills and therefore should be more acceptable to surrounding residents.

DISADVANTAGES

- Greater initial investment than conventional transfer station

OTHER CONSIDERATIONS

Other issues to be examined in deciding whether or not to bale are as follows:

Volume of Waste

There should be enough waste to guarantee utilization of the equipment at a rate of around 100 percent. For the new model of the St. Paul baler, for example, this would be 896 tons per day. Utilization rates between 50 and 80 percent (443 to 716 tons) are in the marginal range. At rates above 80 percent, costs for the baling process are very competitive with costs of conventional disposal with transfer.

Type of Waste

Grass, yard clippings, and leaves cannot be included in concentrations greater than 50 percent by weight, or the bale (St. Paul) will not retain its integrity. Under normal operating conditions such material can be dispersed at the baler plant so that this is not a problem.

Environmental Quality of Landfill Site

Ongoing EPA monitoring tests will establish whether balefills are significantly superior to conventional sites.

CONCLUSIONS

The Environmental Protection Agency recommends that cities generating a sufficient volume of waste (currently defined as greater than 400 tons per day) strongly consider baling, especially if close-in land for disposal sites is unavailable and long hauls are inevitable. Cities with less than this minimum tonnage should examine the prospects of a joint venture with neighboring communities before abandoning the baling concept.

TABLE 24

COST OF ST. PAUL BALER OPERATION AS A FUNCTION OF BALER UTILIZATION AND MACHINE MODEL, 1973 *

Percent of production capacity	137-second-cycle machine			90-second-cycle machine		
	Tons/hr	Tons/day †	Cost/ton	Tons/hr	Tons/day †	Cost/ton
100	36.8	589.4	$2.10	56.0	896.0	$1.65
90	33.1	530.5	2.35	50.4	806.4	1.85
80	29.4	471.5	2.65	44.8	716.8	2.15
70	25.7	412.6	3.15	39.2	627.2	2.55
60	22.0	353.7	4.50	33.6	537.6	3.25

* Assumes bale weight of 1.40 tons and bale volume of 1.33 cu yd.

† Assumes two shifts per day.

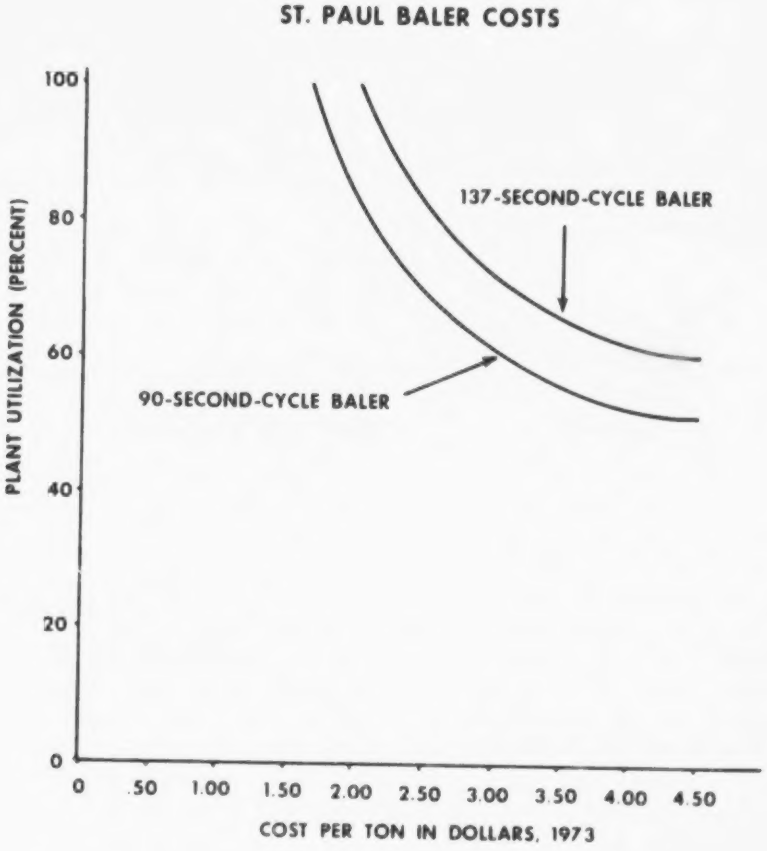

FIGURE. 5. The cost per ton at the St. Paul baling facility increases as plant utilization decreases.

Shredding

Shredding (milling) is a volume reduction process in which solid waste is shredded into a relatively homogeneous material that, in turn, may be landfilled or further processed. European experience with shredded solid waste indicates that there are several potential advantages of shredding solid waste before landfilling it. It was found that shredded waste did not attract vectors, support combustion, or lead to littering or other problems usually associated with the disposal of solid waste on land. The Office of Solid Waste Management Programs is currently aware of over 30 U.S. locations that use or have used shredding equipment for solid waste management and has sponsored several projects and studies concerning the process.

The decisions to be made are whether the total benefits realized by shredding outweigh the cost of such an operation, and whether the environmental effects of a shredded refuse disposal site are acceptable.

COST

Because of the relative newness of shredding technology, firm cost figures are very difficult to establish. For projects in which EPA has been involved, costs ranging from $1.99 per ton up to more than $11 per ton have been observed for actual operations. In due fairness to the shredding concept, it should be noted that any high costs observed have very often been due to the pioneering nature of the projects; that is, because of the necessary debugging process, the mills have not been run at full capacity for sustained periods and consequently costs, including debugging costs, are often spread over a reduced tonnage. In a demonstration project in San Diego using shredding and baling, the cost for shredding 175 tons per day (6 hours' productive time) has been reasonably projected at $1.67 per ton exclusive of land cost. By going to more than one shift per day, this cost could be further reduced because the fixed costs would be spread over an increased tonnage. Projected costs from the Madison, Wisconsin, demonstration project range from less than $3 to nearly $7, depending on the tonnage handled (Figure 6). The Madison figures include the cost of a short haul to the landfill site and landfilling but exclude land acquisition costs. The projections from both demonstration projects use local labor and utlity rates. In the future, with further refinement of the shredding process, costs of well under $2 per ton might reasonably be expected.

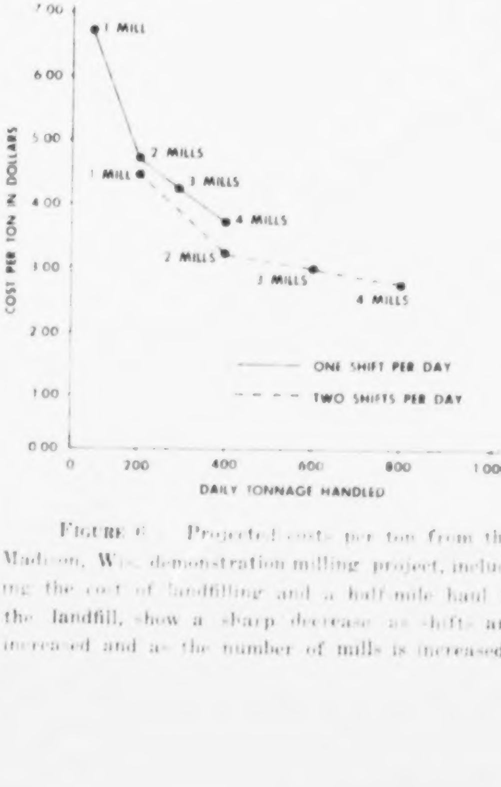

FIGURE 6.—Projected costs per ton from the Madison, Wis., demonstration milling project, including the cost of landfilling and a half-mile haul to the landfill, show a sharp decrease as shifts are increased and as the number of mills is increased.

SHREDDING EQUIPMENT

A wide variety of equipment is available for the size reduction of materials. Much of this equipment is intended for reduction of specific materials, such as shears for auto bodies or crushers for rock. Hammermills are the most common type of equipment now used for the size reduction of municipal solid waste. Other types of equipment such as rasp mills, disk mills, and wet-pulpers have also seen some use with solid waste, but hammermills appear to have the greatest success.

There are basically three types of hammermills: the swing hammer, the fixed or rigid hammer, and the grinder. The swing and fixed-hammer types are similar except that in the swing-hammer type the hammers are pivoted on the rotor, thereby potentially reducing internal jams or damage to the hammers. In the grinder type, which is not a true hammermill, the hammers are replaced by layered rotating discs between which are peripherally located free rotating star wheels that shred the material against the side walls of the housing. To reduce the need for presorting, hammermills are often equipped with some sort of ejection mechanism to remove nongrindable material that might jam or injure the equipment.

Hammermills vary in size depending on the type and amount of material to be processed.

1. Light duty—15 hp TPH* for light wastepaper, cardboard, bottles, cans, garbage, and yard wastes
2. Medium duty—25 hp TPH for normal packer truck waste—including some furniture, appliances, auto tires, lumber, tree trimmings, etc.
3. Heavy duty—30 hp TPH for autos, rubble, heavy metal, etc.

For general municipal solid waste, medium-duty equipment is most often used. Heavy-duty equipment should be considered where there is a considerable amount of bulky waste to shred.

ADVANTAGES

Extends Landfill Life

The Madison, Wisconsin, shredding demonstration project has tended to confirm the positive reports from Europe on the process. It has been found that, because milled waste is not esthetically insulting, it can often be disposed of on land without daily or intermediate cover where hydrogeological conditions permit; however, careful consideration must be given to the character of the input material and necessary leachate control. It also must be recognized that even where regulatory agencies permit landfill of shredded waste without daily cover, the same engineering and operating principles associated with traditional sanitary landfilling techniques must be employed to ensure that the site does not revert to a dump.

Another advantage of this process is that shredded waste is easily placed and compacted and even serves well as material for keeping the disposal site accessible in inclement weather. If there is no need for daily or intermediate cover, and good compaction is readily available, it is easy to see how the life of a land disposal site can be optimized; in some cases, it can be almost doubled. Shredding thus reduces the often burdensome problem of locating suitable cover material and the need to acquire additional land.

Public Acceptance

To date, public acceptance of shredding facilities has been relatively good compared to acceptance of more conventional solid waste processing or disposal facilities. This might be due to two factors. First, the shredding site is usually not the disposal site, and second, the shredded waste is far more unobtrusive in appearance than nonprocessed solid waste. Also, there are no air pollutants from combustion or water pollutants from process waters associated with shredding. However, litter, odor, and vector problems can develop if housekeeping is poor.

Low Cost

The initial investment and operating costs for shredding are relatively low; the increase over that of straight sanitary landfilling is relatively small. Calculation of the economics of shredding should include the savings in hauling costs that may be possible because the shredding facility functions as a transfer station between the collection area and the disposal site.

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* hp/TPH = horsepower required to process each ton per hour of throughput. Thus, the total horsepower requirement of a medium-duty shredder processing 40 tons per hour is 40 TPH × 25 hp/TPH = 1,000 hp.

Where favorable market conditions exist or develop, the sale of materials separated from shredded waste can be used to further offset the cost of shredding or to subsidize the solid waste management system. Shredding can, in fact, enhance the marketability of certain fractions of the solid waste stream.

Most Wastes Can Be Shredded

A large portion of the total solid waste load can be shredded. Some wastes, however, cannot be put through the mill because of size or density or because they are hazardous, have high moisture content, or have other qualities that normally call for specialized handling in any system.

Use With Incineration, Resource Recovery, Other Processes

It has been found that shredding can be used in conjunction with a number of solid waste treatment processes other than landfilling. For instance, bulky combustible waste can be shredded for incineration. Ordinarily many such items have to bypass the incinerator because they are too large to charge or burn well. The cost of shredding bulky combustibles must be compared to the savings made possible by handling and disposing of only about 10 percent of the original volume of these wastes. In locations where a large portion of the waste mix consists of bulky combustibles, it is obvious that the ultimate land disposal site life can be significantly lengthened through the use of shredding. Similarly, the transportation costs of these bulky wastes can be greatly reduced.

Variations of standard solid waste incinerators, such as the vortex suspension burner or the fluidized bed incinerator, require that waste be shredded for proper feeding and combustion. For similar reasons, other thermal processes, such as pyrolysis or use of solid waste as a power plant fuel supplement, may necessitate the shredding of solid waste. Certain solid waste balers also work best when utilizing shredded waste.

Lastly, it appears that shredding is necessary for many resource recovery processes in which feed material of uniform size is needed, such as air classification or the magnetic separation of ferrous metal.

DISADVANTAGES

Materials Handling Problems

There has not been long-term experience in the shredding of solid waste, and many of the operational problems have not been solved. Perhaps one of the major problems encountered in shredding has been the materials handling aspect of feeding the mill and the subsequent removal of the shredded material. Jamming and bridging of the feeding equipment can significantly reduce the throughput of the mill. Uneven feeding can result in uneven hammer loading and wear, as well as surges in power requirements. Unless the shredded material is rapidly removed from the mill, a backup jam may occur.

Component Wear

Another problem area that has contributed significantly to overall cost and downtime is component wear, particularly hammer wear. Recent developments such as reversible rotors, improved hammer tipping materials, and easier access to internal components promise to significantly reduce costs. Bearing wear has likewise been a source of problems, but many of these have been nearly eliminated through proper lubrication, strict specifications, and minimizing of longitudinal movement or vibration of the rotor.

Explosions

Explosions within the mills have also caused problems. The mills are not usually damaged, but provisions should be made for employee safety.

Noise

Noise problems associated with shredding can be eased by the use of sound-deadening material and possibly locating the mill below ground level where conditions permit.

CONCLUSIONS

EPA recommends that cities with a severe shortage of landfill sites and/or cover material consider shredding if hydrogeological conditions permit. Local regulatory authorities should be contacted to determine how present regulations would affect landfilling of shredded wastes. Other than cover requirements, all normal sanitary landfilling procedures must be followed in landfilling shredded waste; under certain conditions, additional consideration must be given to leachate collection and treatment when wastes have been shredded.

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Energy Recovery and Thermal Reduction

Mixed municipal solid waste is composed largely of combustible materials. On the basis of weight, more than 75 percent of the material is combustible, but more important from the point of view of disposal is the fact that greater than 90 percent of the volume can be eliminated by means of thermal reduction. Historically thermal reduction has referred exclusively to the incineration process carried out largely in refractory-lined chambers. More recently, however, solid waste disposal technology has found many new ways of thermally treating refuse to convert it into new forms or utilize its energy value. This includes the development of waterwall incinerators, pyrolysis technology, and various ways to use refuse as a fuel. The advent of strict air pollution control laws and the emergence of a strong environmental concern for conserving nonreplenishable resources has had a very dramatic impact on the status of thermal reduction options. Conventional incineration has been virtually eliminated from current options, and many new systems are being proposed (Table 25).

ALTERNATIVES

Incineration

Municipal incinerators are designed for self-sustained combustion of municipal solid waste under controlled conditions that maximize volume reduction while minimizing the emission of pollutants.

Combustion takes place on a metal grate that is enclosed within a combustion chamber. Air sufficient to complete the combustion reaction is forced into the chamber from below and above the refuse. The hot combustion gases are then passed through air pollution control devices to remove the pollutants, principally particulates, before exhausting the gases to the atmosphere. In addition to the furnace, a complete incineration system consists of a receiving and storage area where solid waste is brought into the plant and held until it can be burned, a method of firing the solid waste into the furnace, the fans and equipment needed to deliver the combustion air to the furnace, the air pollution control system, a stack for discharging the gases to the atmosphere, and a means of removing the noncombustible ashes from the furnace.

Refractory Walls. When the combustion chamber in such a unit is lined with refractory walls and ceilings, the rate at which material can be burned is limited by the rate at which the heat emitted can be safely removed from the system without causing heat damage to the various parts of the facility. Essentially all of the heat must be removed by means of the air and combustion gases flowing out of the unit. In order to protect the unit and still achieve reasonable throughput, considerably more air than is needed to complete the combustion process must be introduced into the furnace. This air, referred to as excess air, carries off the heat of combustion, but in so doing greatly aggravates the problem of air pollution control. This is because the excess air entrains more particulate matter and also because the air pollution control equipment must be increased in size to handle the greater volumes of air. With increasingly stringent air pollution control requirements it has become very costly to build air pollution control systems. The net result has been an almost total abandonment of the refractory-lined incinerator.

Waterwalls. Another type of incinerator consists of a furnace whose walls are constructed of vertically arranged metal tubes joined side by side with metal fins. Radiant energy from the burning of solid waste is

TABLE 25

ECONOMIC AND ENVIRONMENTAL CHARACTERISTICS AND STATUS OF THERMAL REDUCTION AND ENERGY RECOVERY SYSTEMS

System	Companies involved	Capital costs per ton of daily capacity	Status	Air pollution potential	Major product output	Marketing problems	Total operating costs per ton *	Revenues per ton	Net costs per ton
Incineration:									
Retractory-lined units	†	$15,000–20,000	Obsolete; 300 units in use	Cannot economically meet Federal standards	None	—	$8.00–15.00	—	$8.00–15.00
Waterwall units	Nashville Thermal Transfer Corp., IBW-Martin, Rust Engr.	12,000–15,000	Several units operational, 240 to 1,600 tons per day	Can meet Federal standards	Steam	Must satisfy specific needs of customer	9.00–15.00	$6.00	3.00–15.00
Pyrolysis:									
Conversion to gas or oil	Garrett Research & Dev. Company, Union Carbide	10,000–18,000	200-ton-per-day pilot plant under construction	Emissions readily controlled	Oil, gas	Oil needs to be tested. Btu value of gas needs to be increased to extend marketability	10.00–13.50	5.00	5.00–8.50
Heat recovery	Monsanto, Torrax, Devco	14,000–18,000	1,000-ton-per-day plant under construction	Emissions readily controlled	Steam	Must satisfy specific needs of customer	9.50–12.50	4.00–5.00	4.50–8.50
Refuse as fuel:									
Dry-shredded	Horner & Shiffrin, Browning & Ferris, Inc., Waste Management, Inc., Combustion Engineers, Combustion Equipment Associates, Americology	7,000–12,000	650-ton-per-day system in operation	Air pollution tests currently underway at power plant. Combining two sources into one is an advantage.	Fuel	Major market is coal-fired utility boilers. No major problems expected.	10.00–14.00	5.00	5.00–9.00
Wet-pulped	Black Clawson	10,000–14,000	Hardware in use; 150-ton-per-day pilot plant		Fuel	Use of pulp as fuel still needs to be tested	11.00–14.00	5.00–7.00	4.00–9.00
Electrical generation	Combustion Power Co.	—	Research—pilot plant	Emissions should be well below new standards	Electricity	Implications of selling electricity are unknown.	—	—	—
Biological conversion	—	—	Research—lab scale	—	Methane	Unknown	—	—	—

* Includes amortization. The range in costs reflects differences in size and dates of original data.

† Many different companies have constructed this type of system.

absorbed by the tubes and fins and transferred to water passing through the tubes. Additional boiler packages located in the back passages of the incinerator are used to control the conversion of this water to steam of specific temperature and pressure. Units fired by fossil fuels can also be used to superheat the steam for electrical generation. By transferring the heat released through the combustion of refuse to the water, the volume of air needed to keep the operating temperature at acceptable levels can be reduced. The advantage of this is a reduction in the size of the unit and, most importantly, in the size of the air pollution control equipment needed. The volume of gas entering the air pollution control equipment will be about 25 percent of that of an air-cooled, refractory unit. Additionally, the combustion process can be better controlled so that fewer pollutants are entrained in the gas stream.

The smaller volumes of gases can then be easily cleaned using either high-energy-drop scrubbers or electrostatic precipitators. Tests of Chicago's northwest waterwall incinerator have demonstrated that it can meet the Federal limit of 0.08 grain per standard cubic foot.

Residue Treatment. Incinerator residue is permeable and may contain water-soluble inorganic and organic compounds. If water moves through a deposit of residue, leaching can occur. Pollution can occur if the leachate water moves through underlying soil and enters the groundwater. Surface water can also become contaminated where the leachate moves laterally through the surrounding soil and seeps out at ground surface. Therefore, only sanitary landfill methods should be employed to dispose of incinerator residue. A discussion of the recovery of marketable materials from incinerator residue is contained in the section on materials recovery.

Fly Ash Treatment. Fly ash is usually handled along with the residue. In addition to ensuring that it is properly landfilled to prevent leaching, it must also be handled in a manner that prevents it from being air blown. This requires the use of either closed containers or wet sluicing from the point of collection to disposal.

Wastewater Treatment. Wastewaters are produced in an incinerator both from the ash quenching operation and from many types of air pollution control processes. Even if these waters are reused, some discharging will be necessary. Whenever possible, these wastes should be discharged to a sanitary waste sewer for proper treatment. Both pH and settleable solids should be controlled to the maximum extent practicable, whether they are being discharged to an open course or a sanitary sewer. The pH is partially controlled by mixing the quench water and scrubber water, but additional chemical treatment may also be needed. Retention tanks or ponds should be used to remove settleable solids.

Economics. Waterwall construction is more costly than refractory construction, but, as explained above, if both are designed to meet the same air pollution code, the waterwall unit can be smaller than the refractory unit and therefore will cost less to build. Data on several plants built during 1972 and 1973 indicated that capital costs per ton of installed daily capacity for waterwall units are from $12,000 to $15,000.

Operating experience is limited to date, but the costs of operating a waterwall unit appear to be comparable to those of refractory units.

Although the operating costs are similar, the cost of operating a waterwall unit can be offset by the sale of steam. Although potential revenue from steam sales could amount to $3 to $5 per ton of waste processed, it should be pointed out that operators of most waterwall units built in this country to date have not been successful in marketing steam. However, one unit that is currently nearing completion in Nashville, Tennessee, was built specifically to serve a guaranteed long-term steam market.

Successful sale of steam requires an in-depth understanding of the constraints of the market and a religious adherence to the limitations set down by it. Some of the factors which must be considered are as follows:

- Site Selection. The site must be one that is close enough to economically serve the steam market. Both the total distance and intervening obstacles must be considered.

- Value. The cost of the delivered steam must be competitive with costs of alternative supplies of steam available to the customers. If this steam will be replacing an existing source, its value is likely to be considerably less than if it is satisfying a new demand.
- Quantity. The amount of steam to be supplied must be compatible with the customers' needs. If peak loadings cannot be supplied entirely by burning refuse, then standby boilers will be needed.
- Operating Schedule. The incinerator facility must be operated on a basis that best meets the operating schedule of its steam customers.
- Availability of Refuse. The municipality must ensure that it can supply enough refuse to the facility to meet steam output commitments.
- Steam Quality. The steam must be produced at the temperature and pressure that best suits the needs of the market.
- Reliability. The system must include sufficient backup facilities to provide assurance that the steam needs of the customers can be met. This must include contingency plans in the event of a strike or snowstorm that interrupts delivery. The cost of meeting this commitment must be considered in the overall evaluation of the system.
- Excess Steam. The facility must be designed to serve the community's disposal needs, even if there is an interruption to the steam market. Condensing units or a backup sanitary landfill can serve this need.
- Timing. The steam must be available when it is needed. Unanticipated delays in construction of the facility could force steam customers to change to another source of steam.

Pyrolysis

Pyrolysis is the thermal degradation of organic substances in an oxygen-deficient atmosphere. The concept is under development by nearly a dozen different private and public organizations. The primary motivation is the desire to develop a system wherein solid waste can be converted into a storable, transportable fuel—either liquid or gas. Once this can be done, many of the constraints that limit the marketability of steam will be minimized. At this time, several pyrolysis systems have been demonstrated at the pilot plant level (4 to 150 tons per day), but no full-scale systems are operational. One full-scale plant is currently being built, and two other systems are being pilot-tested at the 200-ton-per-day range. By 1980, sufficient experience should have been gained to make this a viable option for widespread utilization.

Products. In a pyrolysis or partially pyrolytic system, high temperatures of 1,000 to 2,000 F and low availability of oxygen result in a chemical breakdown of the waste organic material into three component streams: a gas consisting primarily of hydrogen, methane, carbon monoxide, and carbon dioxide; a "tar" or "oil" that is liquid at room temperature and includes organic chemicals such as acetic acid, acetone, and methanol; and a "char" consisting of almost pure carbon plus any inerts (glass, metals, rock) that enter the process unit. Residence time, temperature, and pressure can be controlled in the pyrolysis reactor to produce various combinations of gas, oil, and char.

Residue. Pyrolysis, like incineration, produces a residue that must be properly disposed of. In certain pyrolysis systems, where a high-temperature cupola-type furnace is used, the residue is melted into a metallic and glassy frit. Using this technique, it is possible to achieve about 50 percent greater volume reduction than in conventional incinerators. It is also felt that this material is more easily disposed of and in fact would quite likely be usable as an aggregate.

Air Pollution. Air pollution controls are considered to be less costly for pyrolysis systems than for incinerators. Both the amount of particulate air pollutants, such as soot and other particles, and the volume of stack gases are significantly lower with pyrolysis systems.

Energy Recovery From Pyrolysis. The pyrolysis concept has the advantage of including recovery of energy in a number of forms, thus enhancing its applicability. The oil product should prove to be a storable, transportable fuel. The gas could be piped to an adjacent utility or industry boiler for use as supplementary fuel. Gases produced so far have been too low in heat value to be either storable or transportable over long times or distances. However, work is underway to determine the feasibility of improving this gas to pipeline quality. In the system which is furthest developed, the Monsanto LandGard system, the gases are burned on site and the resulting heat is used to produce steam which is then sold for heating.

Costs of Pyrolysis. Complete cost estimates are not yet available for pyrolysis systems. Capital and operating costs are estimated to be comparable to those of waterwall incinerators. Capital costs are estimated at $10,000 to $18,000 per ton of daily capacity. The 1,000-ton-per-day plant being built in Baltimore, Maryland, for instance, will cost $15,400,000. Total operating costs are expected to be in the range of $9.50 to $13.50 per ton. Revenues received from the sale of products would reduce the costs to between $1.50 and $8.50 per ton.

Pyrolysis Systems. The following is a description of several pyrolysis systems with which EPA is most familiar. This list is not presumed to be all-inclusive, nor is it meant to imply endorsement by EPA.

Garrett Research and Development Company. A 200-ton-per-day Garrett system is currently under design for San Diego County as a demonstration project supported by EPA. The plant should be operational by late 1975. Mixed municipal solid waste will be coarsely shredded and then separated mechanically into a light fraction and a heavy fraction. The light material will be dried and shredded to a very fine particle size, practically a powder, before undergoing pyrolysis at a temperature of about 900 F. No auxiliary fuel is required. An oil-like liquid with a heat value of about 75 percent that of No. 6 fuel oil will be used as supplementary fuel in an existing San Diego Gas & Electric Company boiler. Garrett estimates that one barrel of oil can be produced from a ton of solid waste.

The heavy waste fraction will be processed further to take out ferrous metals and glass. Ferrous metals will be removed by an electromagnet. Glass will be removed as a mixed-color glass cullet by a froth flotation process.

The system is an outgrowth of nearly 5 years of intensive research by Garrett into methods of producing synthetic fuels. A 4-ton-per-day pilot plant is currently operating in LaVerne, California.

Union Carbide Corporation. The Linde Division of Union Carbide is constructing a 200-ton-per-day pilot plant in South Charleston, West Virginia. The plant should be operational in 1974.

The system is characterized by its slagging vertical shaft furnace, its use of pure oxygen rather than air, and by not requiring shredding. The pyrolysis gas is neither transportable nor storable, but can be either combusted to drive a gas turbine to generate electricity or used as a supplementary fuel in an adjacent industry or utility boiler.

Union Carbide has completed laboratory research on the methanation of the pyrolysis gas to improve it to high-quality pipeline gas.

A 5-ton-per-day pilot plant is currently operating in Tarrytown, New York.

Carborundum Company (Torrax). The Torrax Division of Carborundum has operated a 75-ton-per-day pilot plant in Erie County, New York, for several years under sponsorship of EPA, the New York State Department of Environmental Conservation, and the county of Erie. The system is similar to Union Carbide's: vertical shaft furnace, slagged residue, no shredding. However, the system is characterized by its "Super Blast Heater," a heat exchanger in which air is preheated by auxiliary fuel to 2,200 F and directed into the furnace.

The pyrolysis gas can be either combusted on site to generate steam or piped to an adjacent industry or utility boiler for use as supplementary fuel. One utility is currently considering adding a Torrax furnace to its electric power plant; the hot, combustible gases would be discharged directly into the existing coal-fired boiler.

Monsanto Corporation. The Enviro-Chem Systems Division of Monsanto has developed the LandGard system, which features shredding, a rotary kiln reactor, and the use of auxiliary fuel oil.

A 1,000-ton-per-day demonstration plant is under construction in Baltimore, Maryland. The project is sponsored by the City of Baltimore, EPA, and the Maryland Environmental Service. The plant should be operational in 1974.

The LandGard system is being designed and constructed by Monsanto under a turnkey contract with performance guarantee provisions. Monsanto is guaranteeing throughput at 85 percent of design capacity, particulate emissions to meet local and Federal standards, and the putrescible content of the residue to be less than 0.2 percent. To back up its guarantee, Monsanto's maximum payback liability is $4 million, or about 25 percent of the contract price.

The plant is being designed to handle mixed municipal solid waste, including tires and bulky wastes. All incoming waste will be shredded and then conveyed to a rotary pyrolysis kiln. Fuel oil will be combusted to provide heat for the pyrolysis reaction. The pyrolysis gases leave the kiln and will then be combusted in an afterburner. The hot afterburner exhaust gases will pass through waste heat boilers that generate 200,000 pounds of steam per hour for sale to Baltimore Gas & Electric Company. The steam will be used for downtown heating and cooling. Boiler exhaust gases will be scrubbed and dehumidified.

The pyrolysis residue will be water quenched, and magnetic metals will be recovered. Water flotation and screening processes will separate the char residue, which must be landfilled, from a glassy aggregate fraction that will be used as aggregate for city asphaltic street construction.

The 1,000-ton-per-day unit was developed from a 35-ton-per-day pilot plant that Monsanto operated in St. Louis for nearly 3 years.

The pyrolysis gas can be combusted on site for steam generation as planned for Baltimore, or it can be used as supplemental fuel in an adjacent industry or utility boiler.

Solid Waste as a Fuel

Solid waste can be used in solid form as a substitute for conventional fossil fuels in existing or newly designed combustion units. The major markets for solid waste fuel are (1) utility steam electric boilers, (2) industrial steam and steam electric boilers, and (3) downtown steam and chilled water distribution utilities.

The prerequisite for entry into these markets is that the boilers must be capable of handling ash—both bottom ash and fly ash. All boilers designed to burn coal have ash handling equipment. Although many coal-burning boilers have been retrofitted to burn oil or gas, the ash handling equipment is still operable in most cases.

There are two ways to enter the market: (1) construction of a new boiler or (2) modification of an existing one. It is usually less expensive to modify an existing boiler than to build a new one.

The largest and most readily available existing boilers are electric utility boilers. Because most of these boilers are suspension-fired (the fuel burns in midair in a residence time of 1 or 2 seconds), the pieces of solid waste fuel must be reduced in size (by shredding, milling, or pulping) so that they can be burned in the boiler's short residence time. The burning of prepared solid waste as a supplement to coal in an existing utility boiler has been demonstrated in St. Louis.

Another process to prepare solid waste for use as fuel is wet pulping, a technique demonstrated at Franklin, Ohio. Because pulped waste has a higher moisture content than shredded waste (50 percent as compared to 30 percent), specialized boilers may be necessary, as described below.

Shredded Waste as Fuel. The shredded waste fuel system demonstrated in St. Louis shreds mixed municipal wastes, separates combustibles from noncombustibles, and burns the combustibles in an existing coal-fired electric power generating boiler. Magnetic metals are separated from the other noncombustibles and sold to a steel mill for remelting. The remaining glass, aluminum, and other nonmagnetic materials can be further separated for resale when technology and economics permit. The concept has several advantages: the fuel, ferrous metals, and other materials recovered from the waste have value, and since 95 percent by volume of the system's throughput is recovered, the community's landfill requirements are reduced. There is less air pollution, better use of land, and conservation of natural resources.

Although the fuel has been tested successfully only in coal-burning utility boilers, utility personnel and boiler manufacturers believe that solid waste fuel can be burned as a supplement to oil as well as coal, provided that the boiler has bottom and fly ash handling equipment.

Every 100 tons of solid waste put through the system results in 70 to 80 tons of fuel at 10 million Btu's per ton, 6 to 7 tons of magnetic metals, and 13 to 24 tons of material containing glass, aluminum, other nonmagnetic metals, and mixed wastes.

Effect on Landfill Requirements. The processing residue (the noncombustible waste fraction, less magnetic metals) must be put in a sanitary landfill and is about 5 percent by volume and 13 percent by weight of the incoming raw waste. Bottom ash and fly ash (about 25 percent by weight) remaining after combustion may be sold for use as fill material or construction material. If it cannot be sold, it must be landfilled; the utility may take responsibility for disposal.

The capability of a solid waste fuel processing plant to accept bulky wastes, such as large appliances, tires, furniture, and automobiles, is simply a function of design. Shredders and conveyors must be sized to handle larger materials. Any noncombustible or oversized material will be separated from the waste fuel by the air classification process. Except for tires, most bulky wastes have little significant fuel value.

The capability to dispose of both bulky wastes and municipal wastes at the same facility must be weighed against the added costs to the system of handling the bulky wastes.

It should be noted that resource recovery is not a panacea. In addition to the process residuals mentioned above, there will be no reduction in landfill space needed for certain types of waste (construction, demolition, etc.) that cannot be processed in a shredded fuel system. Methods for recovering and utilizing special problem wastes are being developed.

Air Pollution. Burning solid waste as a supplement to coal is expected to reduce sulfur emissions from power plants with no increase in particulate emissions. Air pollution tests were made in December 1973. When the results are known, they will be made available to the public through the EPA Regional Offices.

Pulped Waste as Fuel. The pulped fuel concept is an extension of the wet-pulping separation technique demonstrated at Franklin, Ohio, by the Black Clawson Company. For a description of the wet-pulping system, see the section on materials recovery. After pulping and removal of noncombustible materials, the remaining material, despite the moisture content, is almost entirely combustible. Indeed, it is the wet-pulping separation technique that permits the removal of almost all noncombustibles. The resulting pulped fuel, with a moisture content of about 50 percent after dewatering, can be used as the primary fuel in boilers that are designed to handle high moisture content materials, such as wood bark from papermill wastes or sugar cane wastes. The pulped fuel could also be dried further and used as a supplementary fuel in existing boilers burning coal or oil.

Recovery of heat energy from burning this fuel has not been demonstrated on a large scale. Tests by the Black Clawson Company have been encouraging enough for the company to promote the system in the waste disposal market. The company has submitted bids to two cities in which the dewatered pulped fuel would be burned as the only fuel in a boiler for the generation of steam or electricity on site.

Economics of Shredded Fuel Systems. The following costs and revenues apply only to a system using shredded fuel. Costs of the pulped fuel system are not available.

The costs presented here are typical for a total system, including boiler modification. They were derived from engineering estimates submitted to several communities.

Capital costs for a 1,000-ton-per-day shredded solid waste fuel system, including the waste processing facility, transport facilities, firing facilities, and boiler modification, would be on the order of $7 to $12 million.

The following figures reflect typical projected costs per ton of operating the system, including amortization at 6 percent for 15 years.

Processing	$ 8 to $10
Transportation	1 to 2
Firing	1 to 2
	$10 to $14

The value of the products recovered, per ton of raw waste, can vary as follows:

Fuel	$2 to $8, based on $.25 to $1 per million Btu
Magnetic metals	$0 to $1, based on up to $20 per ton of metal
Fly ash	Sold by utility to cement manufacturers
Other materials	Price not yet determined

The value of the shredded fuel varies with the cost of alternative fuels. For example, if oil costs 80 cents per million Btu then the solid waste could be worth as much as $6.40 per ton of raw waste. (There is 10 million Btu obtained per ton of shredded fuel, 8 million Btu from every ton of raw solid waste.)

The recovery of fuel from solid waste potentially creates mutual benefits for the community and the utility. Some benefits may be expressed in dollars; others may not. For example, the community can benefit from lower waste disposal costs, less air pollution, and longer landfill life. At the same time, the utility can benefit from lower fuel costs, a reliable source of low-sulfur fuel, and an opportunity to provide a community service.

In actual practice, then, the value of the solid waste fuel is established according to how the community and the utility perceive the possible benefits. Any price associated with the solid waste fuel must be negotiated.

ADVANTAGES OF ENERGY RECOVERY

In addition to easing energy shortages, energy recovery offers the following advantages over conventional waste management methods:

- Landfill requirements can be reduced. The present landfill can be used longer; and the task of finding the next landfill site will be less urgent.
- Finding a site for an energy recovery plant may be easier than finding a site for a landfill or conventional incinerator.
- Energy recovery is environmentally preferable because total pollution is reduced when compared to a system that includes incineration for solid waste disposal and burning fossil fuels for energy.
- Public opinion is becoming stronger in favor of energy recovery. Many communities are opposing new solid waste management ventures unless they include resource recovery. Some communities have even said that they would pay more for resource recovery because of its environmental benefits.
- Energy recovery appears to be more economical than environmentally sound conventional incineration or remote sanitary landfilling.
- The future prospects for favorable economic justification for energy recovery are very good because of the soaring costs of fossil fuels and increasing environmental constraints being placed on other alternatives.

DISADVANTAGES OF ENERGY RECOVERY

- Most systems will not accept all types of wastes or will still have a residual. Therefore a sanitary landfill will still be needed as a part of the total system.
- Developmental work is still underway on many of the energy recovery options. This could cause a delay in making decisions.
- The municipality will have to market recovered products. This is a new task for most municipalities, requiring special skills and possibly changes in municipal regulations regarding the disposition of "surplus property."
- Specific needs of the energy market may dictate parameters of the system design.

This could include type of facility, size, site location, or operating hours.

CONCLUSIONS

Conventional refractory-walled incinerators have become obsolete because of the high cost of air pollution control. Waterwalled incinerators can be competitive economically with other resource recovery methods provided stringent steam market constraints are adhered to.

Use of shredded solid waste as a supplementary fuel has been proved to be a technically feasible alternative, with few questions remaining to be answered. Utilizing pulped solid waste as a fuel appears technically feasible; however, this has not yet been demonstrated on a large scale.

The production of gas and oil through the pyrolysis of solid waste looks very promising, especially in the light of rising fuel costs. However, these systems should be operated at full scale before they are accepted by cities as a viable resource recovery alternative.

If a community desires to implement a resource recovery system now, it should consider waterwall incineration and use of shredded solid waste as a supplementary fuel, recognizing that there are still economic uncertainties inherent in solid waste fuel systems. If a community has a year or so to make the decision about building a system, they should delay the decision until then because by that time the degree of economic viability of solid waste fuel systems should be much clearer. If the decision-making time is from 2 to 5 years away, oil or gas pyrolysis should also command major emphasis in the community's planning, for these systems should be fully demonstrated during this time. It should be remembered, however, that the time between system selection and actual operation—the time for procurement, design, construction, and shakedown operations—could conceivably be as long as 5 years. This must be considered when determining the lead time available for decision-making.

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Materials Recovery

The decision to be made is whether or not to engage in recovering the various materials in solid waste and to what extent. In this context materials recovery is considered to be any manual or mechanical process in which one or more of the various components in the solid waste stream are separated, concentrated, and sold. The recovery of steel cans and other ferrous metals from the waste stream using a magnet is an example of one type of materials recovery. Materials recovery systems vary in cost, complexity, and risk from the relatively simple process described above to systems that extract not only ferrous metals, but also glass, paper, and aluminum and other nonferrous metals from the waste stream.

The decision to proceed with such a system is based primarily on costs versus benefits and on anticipated technical feasibility, although there are likely to be other constraining prerequisites for many of these systems.

ALTERNATIVES

There are two basic kinds of materials recovery: precollection and postcollection. Precollection recovery, recovery before the materials become mixed in a collection vehicle, is discussed in detail in the section on source separation. This section will deal with postcollection materials recovery, that is, recovery of marketable materials from mixed municipal solid waste.

There are three approaches to implementing such a materials recovery system.

Complement to Land Disposal

A growing number of communities are adding shredding and ferrous metal recovery systems to their landfill operations. Shredding of wastes before landfilling may be used to improve landfill operations and reduce landfill volume requirements (see the section on shredding). Shredding also provides the important first step in a materials recovery system of "liberating" the various components from each other. Ferrous metals are then magnetically extracted. As new separation techniques are demonstrated to be technically feasible, they may be added to the system.

Complement to Energy Recovery Systems

Materials recovery technology is being developed to recover the various noncombustible materials either before or after energy recovery takes place.

Total Materials Recovery Systems

Systems are now being developed which recover as many of the components of the waste as are economically feasible. An example of this approach is the EPA demonstration project in Franklin, Ohio.

ADVANTAGES

A community can receive the following benefits through implementation of a materials recovery system.

Resource Conservation

Net environmental benefits can be achieved through materials recovery. Through recycling, the drain on limited natural resources is reduced. Also, the manufacturing of products from recycled materials has been shown to be less polluting in most cases and requires less energy than manufacturing which relies on virgin materials.

Reduced Landfill Usage

At the very least, any materials that can be easily removed from the solid waste stream and recycled will reduce the quantity of the remaining waste which must be disposed of.

Lower Disposal Costs

Getting rid of solid wastes, even through resource recovery techniques, will probably never result in actual profits for the waste management system. However, the sale of recovered materials may generate enough revenue to pay not only for the increased cost to the system of separating and marketing the materials but also for some of the cost of the overall disposal operation.

Citizen Support

The implementation of a separation system is in consonance with mounting citizen concerns for the environment. Siting should be less of a problem for resource recovery facilities than for conventional disposal facilities.

DISADVANTAGES AND RISKS

Still-Emerging Technology

The degree of technological risk varies with the complexity of the system. Adding a magnetic separator to pull out ferrous metals at a shredding landfilling operation should have a minimal risk, but in general the methods of recovering other materials that are marketable are still in stages of development. There is a great deal of work going on in this field in private industry, universities, municipalities, and the Federal Government. Many concepts are now being demonstrated; some of the demonstrations are described later in this section.

Economic Risks

Due to the newness of this field, well-documented cost and performance information on commercially available equipment that is actually being used to process solid waste is largely unavailable. The economic feasibility is primarily based on projected maintenance costs, the separation system's recovery rate or yield, and an assumed value for the output product. These three items in particular should be scrutinized during the decision-making process. The economic evaluation also depends, of course, on capital costs, operating costs, and product transportation costs, but these estimates are generally more reliable than the previous three.

Marketing Problems

The payoff for a materials recovery system is the sale, at a reasonable price, of the extracted materials. Marketing tactics and negotiations with purchasers represent untested waters for most municipalities and this aspect of the total system should not be underplayed. The community should prepare itself with as much knowledge as possible about the marketplace they are about to enter. Of particular importance are the precise material specifications of the purchaser. These should be closely compared to the anticipated quality of the separated materials. Prior to the commitment of capital funds the community should secure as binding and explicit a commitment as possible from the purchaser. The best would be a contract which specified acceptable quantity, quality, price, transportation or transfer mechanism, and term of the agreement.

The risks noted above may be reduced, but never eliminated, through the use of a private operating contractor or system promoter. The execution of an equitable contract with the private sector is not a straightforward task here either, but this option may reduce the community's headaches in some areas and shorten the implementation period. The municipality should be aware, however, that it can never totally eliminate the risk factors, and therefore the responsibility to scrutinize and evaluate these factors continues. Finally, the community should expect to pay something extra for any special services provided or any risks shared by the private sector.

PREREQUISITES TO SUCCESSFUL IMPLEMENTATION

Markets

A comprehensive market survey specific to the local area must indicate that the recovered materials will in fact be purchased at a reasonable price.

Early discussions with potential buyers are extremely important in order to make sure that the separation system produces materials of sufficient quality and quantity to be useful to the buyer. Any conclusions reached should be reinforced through a contractual agreement before committing funds to construct the facility.

Shredding

Even the simplest form of materials recovery, ferrous metal extraction, requires at least some processing of the solid waste stream to open up paper and plastic bags and "liberate" the tin cans. This function is performed by some form of shredding operation, which can vary from an extremely coarse shredder, little more than a bag opener, to a more sophisticated shredder that reduces all the incoming materials to particles less than a cubic inch in size.

This size reduction equipment can be quite costly, ranging up to hundreds of thousands of dollars. The many benefits that shredding alone offers to a solid waste handling and disposal system (discussed in the section on shredding) are sufficient to justify the capital expenditure in some cases.

Current economic projections indicate that the revenues from the sale of the recovered materials cannot completely offset the added cost of the shredding operation. Therefore, to add a materials recovery system onto a disposal operation that does not already include a shredder would increase the net costs of the whole operation. This increase must be weighed against the auxiliary benefits that shredding provides.

If the solid waste management program has already justified the need for a shredder to improve the disposal operations, then the additions of various levels of materials recovery appear to be very attractive. That is to say, the revenues generated can more than offset the equipment and operating costs required to perform the separation.

Minimum Size

Capital-intensive facilities require large throughputs to achieve reasonable processing costs per ton. Even the addition of a shredder alone could probably not be justified by a small community with less than, say, 150 tons per day of solid waste. The larger the facility—up to 2,000 or more tons per day—the lower the cost per ton. This type of material recovery system may thus be ruled out for smaller communities unless several combine their wastes at one location for processing. Separate collection of newspaper is not so constrained and may be appropriate for even the smallest communities (see section on source separation).

TYPES OF RECOVERY ACTIVITIES

Manual Separation

Handpicking is a long-used form of separation. In this type of operation, a conveyor passes the solid waste by a group of workers who pick out the valuable components by hand. This type of operation has a number of serious drawbacks. It can be a very costly form of separation. Secondly, it is a limited separation because the pickers can usually extract only the bulky materials. Finally, there are potential health and safety hazards, and handpicking is not a job that attracts conscientious workers. Therefore, EPA does not recommend this practice.

Handpicking of bundled newspapers is, nevertheless, being promoted by the National Center for Resource Recovery and Americology, Inc. They propose that homeowners bundle their newspapers before they set them out for collection. The bundles are thrown in the truck with the rest of the wastes, and, at the processing facility, these bundles are handpicked from a conveyor and set aside to be sold.

Composting

Composting of municipal solid waste has been practiced in Europe and the United States for many years. European activity in composting has included research in such diverse areas as engineering technology, public health and pathogen survival, use in strip mine reclamation, use in vineyards, and use in general agriculture. The technology of composting is well advanced, and there are no real technological barriers to making compost.

In the United States, composting plants have been established in various communities over the last 20 years. In general, these plants have met with little success and most have closed. The major problem for these plants is the lack of a viable market for the compost. Currently, only one plant, Altoona FAM, Inc., Altoona, Pennsylvania, is known to be operating on a regular basis.

In the Fairfield-Hardy process used at Altoona, solid waste is ground in a wet-pulper and passed through dewatering presses before it is fed into the digestor for a 5-day decomposition cycle. The material is stirred in the digestor by augers suspended from a rotating bridge in the circular tank. Air is provided by means of a blower and air pipes embedded in the floor of the tank. The digestion system of Fairfield Engineering Company appears to offer a superior engineering design, a more automated operation than other composting techniques, and a superior humus product.

Ferrous Metal Recovery

Ferrous metal recovery is a significant revenue generator for three reasons. There is a significant quantity of ferrous metal, around 7 percent, in the solid waste stream. The value of this metal is typically $12 to $20 per ton. Finally, ferrous metals are relatively easy to extract.

The technology for extracting ferrous metals is readily available, but upgrading the separated product into a saleable material may also be required in some cases. Initial attempts at ferrous metal recovery have resulted in products that were contaminated with paper and other organic materials. Some purchasers found the density undesirable.

There are three basic markets for recovered ferrous metals: reuse in a steel mill, in precipitation of copper from low-grade copper ore, and in the detinning industry, which recovers the valuable tin from the tin cans.

Each of these markets has specific requirements for the ferrous metals that they will buy. The upgrading technology to meet these requirements is now being developed. It is important to note that these market constraints may be significant factors in selecting the type of shredder to be used in the initial processing step. Some shredders such as ring mills and wet-pulpers tend to ball up the tin cans, which makes them less desirable for copper precipitation and detinning but acceptable for the steel industry.

Paper Recovery

Paper represents 30 to 35 percent of municipal wastes, and, at a value of $15 to $35 per ton and up, the sale of the various paper fractions can be a large source of revenue. It is important to note that paper has a higher value when it is reused as paper than when it is used as an energy source.

There are three basic approaches to paper recovery from solid waste: separate collection of newspaper and corrugated paper, wet separation of paper fibers, and dry separation of paper fibers. Separate collection of newspaper and corrugated paper are discussed in the section on source separation. Wet separation of paper fibers has been demonstrated in Franklin, Ohio, and is discussed later in this section. This recovered paper pulp is an unfamiliar material to paper dealers, and so the marketability of this material is still being developed. Dry separation of paper is not technically feasible yet, but there are a number of attempts underway to develop feasible systems.

Glass and Aluminum Recovery

Glass and aluminum recovery equipment is now being developed, but their technical and economic viability are uncertain at this time. The EPA demonstration projects in Franklin, Ohio, and Lowell, Massachusetts, will investigate these issues.

Glass represents between 6 and 10 percent of the solid waste stream. Its value is between $12 and $20 per ton. However, if current soda ash shortages continue, the value of recovered glass may increase. (Soda ash is the chemical needed to produce glass from sand; it is not needed when reclaimed glass is used instead of sand.) Color-sorting into green, amber, and clear fractions increases the value and marketability of the glass.

Aluminum makes up less than 1 percent of the solid waste stream, but this component has an extremely high value of around $200 per ton. This component therefore could be an important revenue generator, and much technology development is underway to separate and concentrate this material. Because of its value, marketing the recovered aluminum is not expected to pose any significant problems.

EPA PILOT PLANTS

Wet Separation and Disposal System, Franklin, Ohio

System Description. Franklin's solid waste processing facility, developed by the Black Clawson Company, has a design capacity of 150 tons per 24-hour operation and is made up of three separate subsystems: a solid waste disposal system, a paper fiber recovery system, and a glass and aluminum recovery system (Figure 7).

The disposal system, called the "Hydrasposal System," consists primarily of a wet-

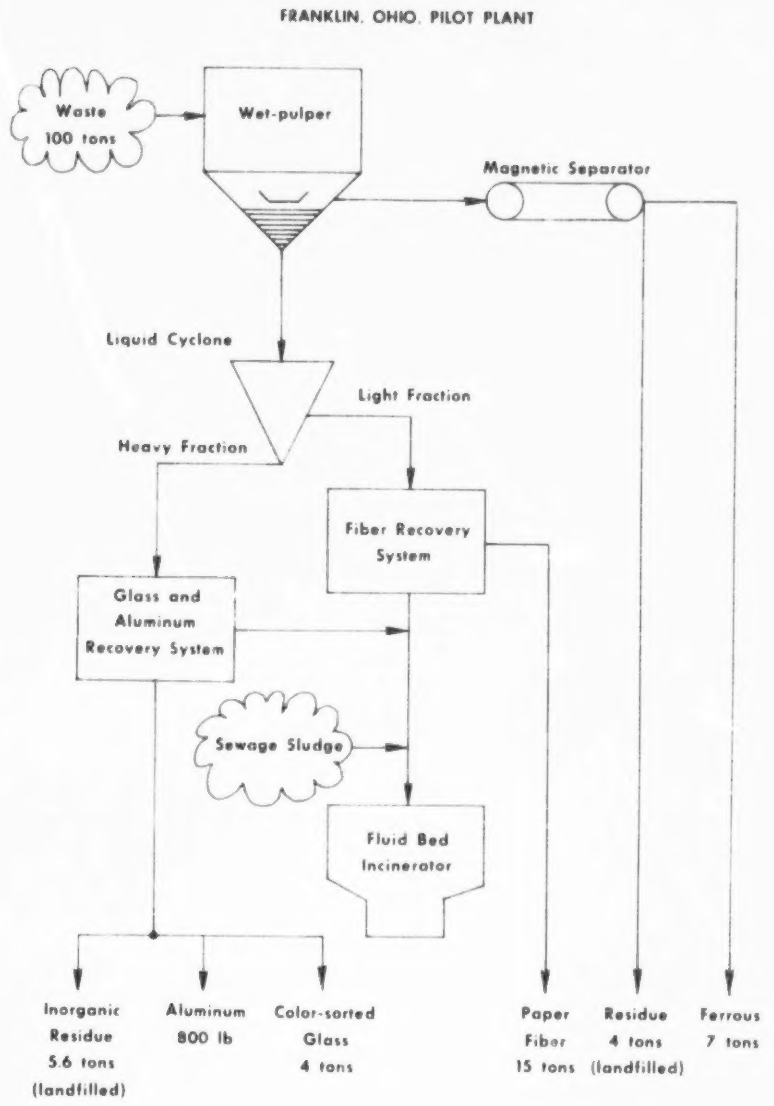
FRANKLIN, OHIO, PILOT PLANT
Waste
100 tons
Wet-pulper
Magnetic Separator
Liquid Cyclone
Light Fraction
Heavy Fraction
Fiber Recovery
System
Glass and
Aluminum
Recovery System
Sewage Sludge
Fluid Bed
Incinerator
Inorganic
Residue
5.6 tons
(landfilled)
Aluminum
800 lb
Color-sorted
Glass
4 tons
Paper
Fiber
15 tons
Residue
4 tons
(landfilled)
Ferrous
7 tons

FIGURE 7. The Franklin, Ohio, pilot plant for the demonstration of a wet separation and disposal system consists of three disposal and recovery subsystems: a solid waste disposal system that includes a ferrous metal separator, a paper recovery system, and a glass and aluminum recovery system.

pulper, a liquid cyclone, and a fluidized bed incinerator. Wastes delivered to the Franklin plant by private contractors and individual citizens are fed by a conveyor into the pulper. The pulper is somewhat like a kitchen sink disposal unit; it consists of a tub 12 feet in diameter with a high-speed cutting blade in the bottom driven by a 300-horsepower motor. Water is mixed with the solid wastes in the pulper, and all soft and brittle materials are ground into a slurry. Large pieces of metal, cans, and other nonpulpable materials are thrown out the side of the pulper and down a chute that leads to a specially designed bucket elevator known as the "Junk Remover." These materials are washed, then conveyed under a magnetic separator where steel cans and other ferrous objects are separated for recycling. The nonmagnetic materials are buried in the plant's sanitary landfill.

The slurry, which contains almost all of the organic materials plus most of the glass, small pieces of metal, ceramics, and much of the aluminum, leaves the wet-pulper through a perforated plate beneath the blade. The slurry is then pumped to the liquid cyclone, where the heavier materials such as glass, metals, ceramics, and wood are separated from the lighter fibrous material by centrifugal action.

After the metals and glass are removed, the slurry moves into the fiber recovery or "Fibreclaim" system. In this process the longer paper fibers that can be used in making paper are mechanically separated. The separation is accomplished by a series of screens that isolate the paper fiber from the coarse organic materials, such as rubber, textiles, leather, and yard wastes; and the fine contaminants, such as food waste, paper coatings and fillers, shorter paper fibers, and the very small pieces of glass or dirt. The recovered fibers are pumped to the Logan Long Company, about a half mile away, where they are used to make felt paper for asphalt roofing shingles.

The heavier materials ejected from the liquid cyclone are conveyed over to the glass and aluminum recovery system, which was developed by the Glass Container Manufacturers Institute. The system uses a series of screening and classifying operations to extract extraneous materials and produce an aluminum-rich concentrate which will be upgraded for recycling and a glass-rich stream. The stream of glass particles is passed through an optical sorting device, developed by the Sortex Company of North America, which separates the glass into clear, amber, and green fractions suitable for use in making new bottles. The aluminum will be sold to Alcoa and the glass will be sold to a number of local glass-manufacturing plants (Table 26).

The nonrecoverable combustible material from the fiber recovery system and the glass recovery system are combined and sent to the fluid bed incinerator, the final step in the Hydrasposal System. The incinerator is a vertical cylindrical unit with a 25-foot inside diameter and was supplied by Dorr Oliver, Inc. Air is blown upward into this unit through a layer of hot sand. The organic residue is thus blown into the fluidized bed of sand, where the combustibles burn completely. The exhaust gases pass through a venturi scrubber that removes the ash particles. The gases discharged to the atmosphere meet Federal air pollution control standards.

Status of Project. The Hydrasposal and fiber recovery systems began operating in June 1971. The plant is now in daily commercial operation, processing about 50 tons of municipal solid waste per day. It is the sole solid waste disposal facility for the city of Franklin and the adjacent area. The glass and aluminum recovery system began operating in August 1973, and the revenues from the sale of these products may reduce the net cost of the operation.

Economics. On the basis of approximately 2 years' operating experience in Franklin, the wet separation of solid wastes into recoverable products appears to be an economically attractive resource recovery and waste disposal option. This, of course, is a judgment that depends upon the costs of alternative means of disposal. The Black Clawson system will not break even without charging a fairly high fee to the users, but even so, indications are that it will be cost competitive with incineration and in some situations may even be competitive with the costs of long haul to distant sanitary landfills.

Capital cost projections for a 1,000-ton-per-day facility would be on the order of $13 to $16 million. Typical projected costs per

Table 26

QUANTITY, QUALITY, PURCHASERS, AND PRICES OF MATERIALS RECOVERED FROM MUNICIPAL SOLID WASTE AT THE FRANKLIN, OHIO, PILOT PLANT[*]

Product	Amount recovered as approximate percent of incoming solid waste (dry weight basis)	Quality	Purchaser	Price per ton[†]
Ferrous metals	7	Roughly equivalent to a No. 2 bundle Generally free of nonmetallics Density may need to be upgraded	Armco Steel Company, Middletown, Ohio	$13–25
Paper fiber	15	Generally considered a lower grade paper fiber Color, grease, and bacterial contaminants are similar to those of mixed wastepaper but fibers are longer and there is less shrinkage Suitable for use in making roofing felt and other construction papers Contaminants can be removed and upgraded for use in higher grades of paper	Logan Long Roofing Plant, Franklin, Ohio	25–65
Glass	4	Expected to be clean and sorted by color	Various glass bottle manufacturing plants in the area	12
Aluminum	0.3	Quality varies at present Developmental work still underway	Alcoa	200

[*] Source: ARELLA, D. Wet processing solid waste for resource recovery and clean disposal; summary report on the Franklin, Ohio, demonstration project. Manuscript in preparation.

[†] April 1974 (price at the plant; transportation from the plant is paid for by the purchaser).

ton for operating the system, including amortization at 6 percent for 15 years, are $12 to $15, while the anticipated revenue is around $7 per ton. This yields a net cost range of $5 to $8 per ton.

Incinerator Residue Separation System, Lowell, Massachusetts

System Description. The U.S. Bureau of Mines and the Raytheon Service Company have developed and demonstrated on a pilot scale a technically feasible method for recovering the metal and mineral values from incinerator residues. The process uses conventional proven mineral engineering equipment along with a series of shredding, screening, and magnetic separation procedures to produce clean ferrous metals, aluminum, copper zinc composites, glass, and an aggregate for road construction. The plant is being designed to handle 250 tons of residue per 8-hour shift. The plant is also being designed to handle various other noncombustible fractions, such as the heavy fraction from an air classifier.

Project Schedule. Construction on the plant will begin in September 1974. Plant operations are scheduled to begin July 1975.

Although the final report on this project will not be available until early 1976, a number of interim reports will be prepared. The first report should be available in mid-1974.

Economics. Despite the preliminary nature of this project, projected costs have been developed.

Capital cost projections for a facility processing 750 tons of residue per 24-hour day, roughly equivalent to 2,000 tons of solid waste input to the incinerator, are on the order of $3 to $4 million. Projected operating costs, which include amortization at 6 percent for 15 years, are $6 to $9 per ton of residue. The anticipated revenue is around $9.75 per ton of residue input, which yields a net profit of $0.75 to $3.75. This net profit could be used to defray a portion of the operating costs for the incinerator.

The revenues above are dependent upon the ability to market the output products of the system. This aspect is one of several to be demonstrated at Lowell.

Some empirically derived costs for a plant of this type have been prepared by the Bureau of Mines and may be obtained by requesting the Bureau of Mines Information Circular No. IC 8533, entitled "Cost Evaluation of a Metal and Mineral Recovery Process for Treating Municipal Incinerator Residues."

Other Separation Systems

The Franklin and Lowell projects are the only materials recovery *systems* presently being demonstrated by EPA. However, EPA's other resource recovery projects are demonstrating various unit operations, such as magnetic separation and air classification, for separating and recovering materials. Virtually all current or proposed energy recovery facilities also involve materials recovery to a significant degree. There are numerous companies involved in private research efforts toward developing resource recovery systems. Generally the approach has been to follow the shredder with magnetic separation and then some form of air classification to concentrate the heavy and light fractions. The heavy fraction is further processed in one of a number of types of equipment that rely on different densities to perform the next separation.

The products from these systems are generally limited to ferrous metals, glass, and aluminum. The light, combustible fraction would be either landfilled, recovered as mixed paper, or used as a fuel in a boiler.

Some of the organizations that are developing these systems are listed here, and additional information may be obtained directly from them:

U.S. Bureau of Mines
College Park, Maryland 20740

National Center for Resource
Recovery, Inc.
1211 Connecticut Avenue, N.W.,
Washington, D.C. 20036

Combustion Power Company
Menlo Park, California 94025

American Can Company
Americology System
American Lane
Greenwich, Connecticut 06830

Raytheon Company
12 Second Avenue
Burlington, Massachusetts 01803

Garrett Research and Development
Company, Inc.
1355 Carrion Road
LaVerne, California 91750

CONCLUSIONS

Complement to Energy Recovery Systems

Materials recovery systems are not incompatible with energy recovery systems. Almost all resource recovery systems being developed include the recovery of both materials and energy. Generally the preferred approach is to recover as many of the materials as the technology and markets can justify and then to recover the energy value in the remaining combustible fractions. This approach can provide a nearly comprehensive resource recovery system by recovering over 90 percent of the material or energy values in the solid waste stream.

Some of the various resources available in our solid wastes represent significant quantities in relation to our national supply and demand for these materials. Generally we have found that manufacturing processes using recycled materials require less energy and create less pollution than processes using virgin materials.

Technological and Marketing Risks

Implementation of materials recovery systems have significant associated risks which should be fully identified prior to committing capital funds. Municipalities should be aware that resource recovery concepts offer tremendous promise, but that their decisions are being made at the forefront of existing technology and that marketing of the materials represents untested waters for most municipalities.

Ferrous metal recovery operations have the least technological risk, while the more complex separation systems are less developed. The Franklin, Ohio, Demonstration Plant is the most highly developed materials recovery system, but the final evaluation of the plant is just now being completed. Many other systems are being developed, but only very limited operational data is available thus far.

This area of technology development is growing rapidly, and it is hoped that full-scale systems will be ready for implementation with minimized risk around 1975–76.

Marketing Groundwork Necessary

The addition of a ferrous metal recovery operation onto an existing shredding facility offers a high degree of probable success *if markets are identified and secured ahead of time.* Currently over 25 communities are recovering and selling ferrous metals in this type of operation, but there have also been a number of dismal failures in cases where the need for advance marketing work was overlooked. EPA cannot emphasize too strongly the need for this marketing groundwork as the first stage toward implementing any resource recovery system.

criteria: cost, institutional factors, resource conservation, environmental effects

decisions: collection, transport, processing, disposal

SANITARY LANDFILLING

criteria: cost, institutional factors, resource conservation, environmental effects

decisions: collection, transport, processing, disposal

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conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation environmental effects decisions collection

Sanitary Landfilling

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost institutional factors resource conservation environment transport, processing, disposal

Sanitary landfilling is an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the solid wastes in thin layers, compacting the solid wastes to the smallest practical volume, and applying and compacting cover material at the end of each operating day.

As the land is the only ultimate disposal sink available, a sanitary landfill is needed for environmentally safe disposal of solid wastes generated by any community. The decision facing communities concerns the extent to which resource recovery, thermal processing, baling, and other volume reduction practices will be employed prior to sanitary landfilling. Thus, the complete solid waste management system must be considered in evaluating the desirability of preprocessing and in the design of sanitary landfills.

SITE SELECTION

Site location is perhaps the most difficult problem in the development of a sanitary landfill. Opposition by local citizens eliminates up to 90 percent of all proposed sites. For this reason, an intensive public information campaign is an essential early step in land acquisition. Assistance for this important step can be obtained from the information program of the EPA Office of Solid Waste Management Programs; support is also available in the form of "expert" testimony before city councils on the environmental acceptability of a well designed and operated sanitary landfill.

In choosing a location for a landfill, consideration should be given to the following variables:

1. Public opposition
2. Proximity to major highway routes
3. Local and State speed limits
4. Load limitations on public highways
5. Bridge capacities
6. Underpass limitations
7. The number of stop lights and major intersections which must be encountered.
8. Railway gates and intersections
9. Haul distance (in minutes)
10. Local traffic patterns and congestion
11. Detours (both existing and proposed)
12. Large valleys and rivers or other physical obstacles separating the landfill site from the major sources of waste generation
13. Special events (fairs, ball games, seasonal events) nearby
14. Recurring acts of God (annual flooding, excessive snowfalls or drifting, mud slides, etc.)

COSTS

The cost of a sanitary landfill consists of the initial investment for land, equipment, and construction, and the operating costs.

Initial Investment

The magnitude of the initial investment depends on the size and sophistication of the landfill. A typical breakdown of the major items that normally constitute the initial investment follows:

1. Land
2. Planning and designing
    a. Solid wastes survey
    b. Site investigation
    c. Design, plans, specifications
    d. Permit application
3. Site development
    a. Land development—clearing, landscaping, drainage features, etc.
    b. Access roads
    c. Fencing, signs
4. Facilities
    a. Administration

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    b. Equipment maintenance
    c. Sanitary facilities, utilities
    d. Weight scales
5. Equipment—tractor, scraper, etc.

Land costs can vary over a large range and depend on local conditions. In most cases, the initial investment for land can be recovered on completion of the sanitary landfill through subsequent development or use of the land. A sanitary landfill may increase the value of the plot of unusable land by making it suitable for recreational or agricultural uses.

Planning and design costs vary, depending on the extent of effort required. At one 50-acre site in an urban area in the Midwest, these costs amounted to about $90,000. Amortization over the site capacity of 475,000 tons yields a unit cost of $0.19 per ton. There is a trend among States to require operators of all sites to apply for and obtain permits to operate. In most States requiring permits, application procedures are well defined. Generally, the applicant must submit for approval information on the site investigation and engineering design. Engineering and legal fees for permit application seldom amount to less than $4,000. Complex site conditions or permit application procedures may result in engineering fees of $9,000 to $16,000 for smaller sites and 8 percent of the construction and equipment costs for larger sites (Table 27). Litigation and prolonged hearings can raise fees to the $40,000 range. Permit application fees vary up to $1,000. Local permit procedures are less predictable, but may require costs of $500 to $5,000, especially where zoning changes or variances are sought.

Site development costs reflect the site's size and the improvements required before it can be used (Table 28). The 50-acre site mentioned above required extensive improvements to protect against groundwater pollution. Site development costs amounted to about $400,000 or $0.84 per ton. A site serving a rural Southern county required an expenditure of $22,400 for development. Site development costs of about $430,000 were incurred at a 1,500-acre site in the Southeast which required special construction for groundwater protection.

Facilities costs amounted to about $100,000 ($0.21 per ton) at the Midwestern site, $13,500 at the rural Southern site, and $150,000 at the Southeastern site.

Equipment costs vary with size and design (Table 29). A tracked machine typically costs around $60,000. The cost should be depreciated over no more than 5 years of operation. In most cases, the equipment will have salvage value after 5 years.

Operating Cost

The operating cost of a sanitary landfill depends on the cost of labor and equipment, the method of operation, and the efficiency of the operation. The principal items in operating cost are:

1. Personnel
2. Equipment
    a. Operating expenses—gas, oil, etc.
    b. Maintenance and repair
    c. Rental, depreciation, or amortization
3. Cover material—material and haul costs
4. Administration and overhead
5. Miscellaneous tools, utilities, insurance,

TABLE 27

SANITARY LANDFILL PERMIT APPLICATION COSTS, BY DESIGN CAPACITY OF SITE, 1973

(In thousands of dollars)

Item	Design capacity of site in tons per day			
	40	100	300	Greater than 300
Engineering design	10	15	20	8%*
Survey	5	7.5	9	10
Borings	4	7.5	15	25
Legal work	3	5	8	1 to 2%*

* Charged as a percentage of site development and equipment costs.

TABLE 28

INITIAL COSTS FOR THREE SANITARY LANDFILLS OF DIFFERENT CAPACITIES, 1973

Item	Site 1 (30 tons per day)		Site 2 (500 tons per day)		Site 3 (600 tons per day)	
	Total (thousands of dollars)	Cost per ton ($)	Total (thousands of dollars)	Cost per ton ($)	Total (thousands of dollars)	Cost per ton ($)
Planning and design	3	0.03	*	*	90	0.19
Site development	22	0.22	430	0.16	400	0.84
Facilities	14	0.14	150	0.60	100	0.21
Equipment †	50	1.25	350	0.54	246	0.52
Total	89	1.64	930	0.76	836	1.76

* Not available.

† Equipment cost was calculated on the basis of a 5-year replacement cycle and then related to total site capacity.

TABLE 29

SANITARY LANDFILL EQUIPMENT PRICES, 1971

Type	Weight (tons)	Approx. price
Track loader	8–11	$ 18,500
	12–16	26,500
	21–23	48,500
	33	69,000
Track dozer	7–12	21,000
	14–20	40,000
	26–32	62,000
	41–42	92,000
	51	146,000
Wheel loader	5–15	24,000
	16–27	47,000
	30–34	76,000
	53–58	121,000
	70–100	161,500
Wheel dozer	17–18	38,500
	28–33	68,000
	28–47	90,000
	72	118,000
Compactor	11–19	34,000
	20–33	60,000
	38–40	84,500

maintenance to roads, fences, facilities, drainage features, etc.

Operating costs in metropolitan Washington, D.C., average about $2.75 per ton. The Midwestern, Southern, and Southeastern sites previously mentioned have incurred costs of about $1.75, $2.50, and $1.35 per ton, respectively.

ADVANTAGES

- Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal.
- The initial investment is low compared with other disposal methods.
- A sanitary landfill can be put into operation within a short period of time.
- A sanitary landfill can receive most types of solid wastes, unlike many other disposal methods.
- Sanitary landfilling may be used to reclaim land.
- It is a simple, easy-to-manage disposal system.

DISADVANTAGES

- Opposition to landfills may be expected from citizens owning land near a proposed site. Extensive public relations programs and possibly legislative action may be required to obtain new sites.
- Proper sanitary landfill standards must be adhered to daily or the operation may result in environmental degradation.

- A completed landfill will settle and require periodic maintenance.
- Any gases produced from the decomposition of the wastes must be controlled.
- Leachate may pollute ground or surface water.
- Obtaining cover material may be difficult and/or costly.

OTHER CONSIDERATIONS

Land Requirements

The land area or, more important, the volume of space required is primarily dependent upon the character and quantity of the solid wastes, the efficiency of compaction of the wastes, the depth of the fill, and the desired life of the landfill.

National estimates indicate that the total residential and commercial solid waste generation rate per person per day is approximately 3.32 pounds. However, the volume requirement for a sanitary landfill should be determined on the basis of specific data and information developed for the individual project. Given a solid waste density of 1,000 pounds per cubic yard in place, and one part (volume) earth cover to cover four parts solid waste, a population of 10,000 people would require approximately 9.4 acre-feet of space per year for residential and commercial wastes.

This volume requirement may be significantly reduced where preprocessing of wastes for volume reduction is employed prior to disposal in the sanitary landfill. Incinerators have been found to achieve average weight and volume reductions of 75 and 95 percent, respectively. Thus, considerably less sanitary landfill volume is required to dispose of the incinerator residue. Baling of solid waste can achieve densities of 1,600 to 2,000 pounds per cubic yard, again decreasing the sanitary landfill volume required. Size reduction measures such as shredding or grinding help to eliminate voids and aids compaction. Shredded or ground solid waste placed in a sanitary landfill can have a density 25 percent greater than that of unprocessed solid waste. In special situations where site geology and hydrology permit, shredded or ground solid wastes may be disposed of on the land without the daily cover required for unprocessed solid waste. Deletion of cover material will in effect increase by about 20 percent the site volume that can be used for solid waste disposal.

Vector Control

In a properly operated and maintained sanitary landfill, insects and rodents are not a problem. Good compaction of wastes and cover material is the most important factor in achieving vector control. A compacted earth cover of at least 6 inches is recommended for preventing the emergence of flies from the fill. Good compaction of the cover material also discourages rodents from burrowing through the cover material. Good housekeeping and daily covering of unprocessed solid wastes are musts for vector control.

Water Pollution

Under certain geological conditions, the burial of solid wastes can cause chemical and microbiological contamination of ground and surface waters. Several investigations have indicated that if solid waste is intermittently or continuously in contact with groundwater, it can become grossly polluted and unfit for domestic or irrigational use.

Proper planning and site selection, combined with good engineering design and operation of a sanitary landfill, can normally minimize the possibility of either surface or groundwater pollution. Some common preventive measures are: (1) locating the site at a safe distance from streams, lakes, wells, and other water sources; (2) avoiding site location above the kind of subsurface stratification that will lead the leachate from the landfill to water sources, e.g., fractured limestone; (3) using an earth cover that is nearly impervious; and (4) providing suitable drainage to carry the surface water away from the site.

Equipment

A wide variety of equipment is available from which the proper type and size may be selected for a particular operation. The size, type, and amount of equipment required at a sanitary landfill depend on the size and method of operation, quantities and times of solid waste deliveries, and, to a degree, the experience and preference of the designer and equipment operators. Another factor to be considered is the availability and dependability of maintenance and repair service for the equipment.

The most common equipment used on sanitary landfills is the tracked or rubber-tired tractor. The tractor can be used with a dozer blade, trash blade, or a front-end loader. A tractor is versatile and can perform a variety of operations: spreading, compacting, covering, trenching, and even hauling the cover material. The decision on whether to select a rubber-tired or a crawler-type tractor, and a dozer blade, trash blade, or front-end loader must be based on the conditions at each individual site.

The crawler dozer is excellent for grading and can be economically used for dozing solid waste or soil over distances up to 300 feet. The large trash or landfill blade can be used in lieu of a straight dozer blade, thereby increasing the volume of solid waste which can be dozed. The crawler loader has the capability to lift materials off the ground for carrying. It is an excellent excavator, well suited for trench operations.

Rubber-tired machines are generally faster than crawler machines. But because their loads are more concentrated, rubber-tired machines have less flotation and traction than crawler machines. Rubber-tired machines can be economically operated over distances of up to 600 feet.

Steel-wheeled compactors are being used increasingly at sanitary landfills. In basic design, compactors are similar to rubber-tired tractors. The unique feature of compactors is the design of their wheels, which are steel and equipped with teeth or lugs of varying shape and configuration. This design is employed to impart greater crushing and demolition forces to the solid waste. Use of compactors should be restricted to solid waste, as they are not suited for application of a smooth layer of compacted cover material. Thus, compactors are best used in conjunction with tracked or rubber-tired machines that can be used for applying cover material.

Other equipment used at sanitary landfills are scrapers, water wagons, draglines, and graders. Such equipment is normally found only at large landfills where specialized equipment increases the overall efficiency.

Equipment size is dependent primarily on the size of the operation. Small landfills for communities of 15,000 or less, or landfills handling 50 tons of solid waste per day or less, can operate successfully with one tractor in the 20- to 30-ton range.

Heavier equipment in the 30- to 45-ton range or larger can handle more waste and achieve better compaction. Heavy equipment is recommended for sanitary landfill sites serving more than 15,000 people or handling more than 50 tons per day.

Sanitary landfills serving 50,000 people or less or handling no more than about 150 tons of solid waste per day normally can manage well with one piece of equipment. At larger landfills, more than one piece of equipment will be required. At sites handling more than 300 tons, specialized equipment can increase efficiency and minimize costs (Table 30).

Provision must be made for standby equipment. It is preferable to purchase a second piece of equipment and use it as a replacement during breakdowns and routine maintenance periods of the regular equipment. Arrangements can normally be made, however, with another public agency or private concern for the use of rental or replacement equipment on short notice in case of a breakdown of regular equipment.

Facilities

A small sanitary landfill operation will usually require only a small building for storing handtools, equipment parts, etc., and a shelter with sanitary facilities for the employees. A single building may serve both purposes.

A large sanitary landfill operation should have a maintenance and storage garage for equipment and an administration building. If the scales are not adjacent to the administration building, a scale house may be needed. Sanitary facilities should be available for employees. In addition, locker rooms and showers should be provided for them.

Completed Sanitary Landfill

Information on the decomposition of buried material in a sanitary landfill is limited. It

TABLE 30

SPREADING AND COMPACTING EQUIPMENT REQUIRED BY LANDFILL SITES HANDLING DIFFERENT AMOUNTS OF WASTE

Waste quantity (tons per day)	Equipment type	Weight (in tons)	Number
Less than 50	Crawler tractor	15	1 †
	Rubber-tired tractor *	10	
50 to 150	Crawler tractor	23	1 †
	Rubber-tired tractor	15	
150 to 300	Crawler tractor	38	2
	Rubber-tired tractor	30	
More than 300	Crawler tractor	38	2 or more
	Rubber-tired tractor	30	
	Steel-wheeled compactor	30	

* Special landfill tires may be desirable; also, tire-chain systems can provide greater demolition effect.

† On small operations, the spreading and compacting machine may also be used to handle cover material.

is extremely difficult to predict the time required for complete decomposition. Many items, particularly paper, have been found unchanged in landfills that had been completed for 15 to 25 years. The rate of decomposition is primarily dependent upon the moisture content and generally takes place at a very slow rate.

Decomposition of the wastes will result in the production of gases, principally methane, carbon dioxide, nitrogen, hydrogen, and hydrogen sulfide. The rate of gas production will usually reach a peak within the first 2 years and then slowly taper off.

Methane gas causes the most concern because of its explosive character. Precautions should be taken to prevent the gas from concentrating in sewers or other structures located on or near the landfill. Methane will seek an easy exit from the fill. Thus, depending on site conditions and design, the methane may flow vertically through the fill and disperse harmlessly in the atmosphere above, or it may flow laterally from the site to concentrate in adjacent structures such as buildings and pipes. Relatively simple and inexpensive techniques can be employed to vent the gas in a controlled manner on site and minimize lateral migration. The potential for recovering, purifying, and marketing this decomposition product is being studied.

Settlement of the landfill is dependent on the depth of the fill, composition, compaction of the material, moisture content, and other factors. Studies have indicated that approximately 90 percent of the ultimate settlement will occur in the first 5 years. The final 10 percent will occur over a much longer period. As a rough indication of the amount of settlement that might occur, several Los Angeles area sanitary landfills, 90 to 110 feet deep, have settled 2.5 to 5.5 feet in 3 years.

Although underground fires rarely occur in a completed landfill, the possibility does exist. All underground fires should be excavated and extinguished. The cell construction of a sanitary landfill helps to confine and restrict the spread of the fire, should one occur.

Completed landfills generally require maintenance because of uneven settlement. Maintenance consists primarily of regrading the surface to maintain good drainage and filling in small depressions that result from uneven settlement. Where ponding of water in depressions is not controlled, seepage into the fill may result in pollution of ground or surface waters.

Completed landfills have been used for recreational purposes—parks, playgrounds, or golf courses. Parking and storage areas or botanical gardens are other final uses. An early formal dedication of the sanitary landfill to its ultimate use as a recreational area may help to overcome local objections to future site locations.

Because of settling and gas problems, construction of buildings on completed landfills generally should be avoided; in several locations, however, one-story, rambling buildings and airport runways for light aircraft have been constructed directly on sanitary landfills. In such cases, it is important for the designer to avoid concentrated foundation loading, which can result in uneven settlement and cracking of the structure. The designer must provide the means to allow the gas to dissipate to the atmosphere and not into the structure.

Multistory buildings can be built over completed landfills using steel and concrete pilings and special engineering design. Because of the complexity of design that must provide for differential settlement and control of decomposition gases, EPA does not recommend this use for a completed sanitary landfill or reclaimed dump site.

CONCLUSIONS

Sanitary landfills are a necessary part of all solid waste disposal systems. As a minimum, they are needed for the disposal of residues from other processes and the materials those systems are unable to accept.

In the short run, sanitary landfilling of unprocessed waste will continue to be the most frequently used and least expensive method of solid waste disposal, especially in areas where adequate land close to the source of waste is available at a reasonable price. However, increasingly, resource recovery and volume reduction processes should be used in conjunction with sanitary landfilling to create a disposal system which is more conserving of both land and resources.

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criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

SPECIAL WASTES

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

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Tires

Used tires pose significant disposal problems for municipalities, industries, and private citizens. Tires, when incinerated, produce unacceptable levels of particulates and sulfur emissions in the air. When landfilled, whole tires will resist compacting and burying efforts and will rise to the surface, where they pose combustion and vector problems. The following describes alternatives currently available in dealing with the tire disposal problem. The alternatives are in four categories:

Retreading: This is discussed separately since actions which encourage retreading can be explored along with the end-use alternative which best suits the community's needs and capabilities.

Immediate: These end uses can be put into effect now, with no capital expenditure.

Short term: These alternatives require minor capital investment in equipment that is currently available or will be available in the near future.

Long range: These end uses require significant capital investment and, in most cases, utilize technology which so far has been demonstrated only on a pilot scale.

ALTERNATIVES

Retreading

While retreading will not solve the tire disposal problem, a resurgence in the retreading industry would forestall the discarding of many tires. (About 175 million are discarded each year.) There are at present approximately 5,000 retreading facilities in the vicinity of municipalities. The possibilities of increasing the utilization of used tires for retreading might be explored with them. There are three main barriers to increased retreading in this country:

- Shortage of usable casings
- Consumer reservations about the quality of retreaded tires
- Increased marketing of inexpensive, name-brand, new tires

The shortage of good casings can be mitigated by the institution and enforcement of tire standards as part of periodic motor vehicle safety checks. A tire that is turned in with tread remaining is much more likely to qualify for retreading than one which has been worn smooth. At the same time, consumer preferences for higher priced quality tires and trends toward radial ply tires will lead to the increasing availability of casings acceptable to the retreading industry.

Consumer preferences for new tires rather than retreaded tires stem partially from the opinion that "new" is better than "used," and partially from experience with poor quality retreaded tires. Retreads are used more widely in commercial fleet operations; 35 percent of their replacements are retreads. These commercial tire users generally keep very good records of tire costs and failure rates and use almost twice as many retreaded tires (on a percentage basis) as passenger tire consumers. Commercial users generally have their own tires retreaded rather than purchase stock retreads. They obtain warranties on retreaded tires that are comparable to new-tire warranties. Other consumers should be advised to also seek such a warranty when buying retreaded tires.

Efforts to establish quality standards for retreaded tires are currently underway at the Department of Transportation, General Services Administration, and the Office of Solid Waste Management Programs, EPA. Once these standards have been developed, the retreaded tire industry will be asked to devise a system of quality control. It is hoped that this will take the form of industry-imposed

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standards for casing inspection and process control.

Once standards have been established and quality control has been reasonably assured, increased government procurement of retreaded tires can follow. Increased Federal procurement of retreaded tires can stimulate other marketing opportunities for the retreading industry, enabling quality retreaded tires to compete more effectively with new tires.

Immediate Alternatives

There are several possible end uses for scrap tires that do not require capital expenditures. They involve reuse of the tires intact or sale to rubber reclaimers. Rubber tires, properly ballasted and secured in groups, apparently make satisfactory artificial reefs. Experimental reefs constructed of tires have been placed along the East Coast by the Bureau of Sport Fisheries and Wildlife. This option is usually limited to coastal areas. Estimates of the cost of reefbuilding, *based on a free supply of tires* assembled at a dockside area, range from $0.50 to $4.00 per tire, depending on the type of reef constructed.

Intact tires may also be used as crash barriers around obstructions near high-speed freeways, as bumpers for docks and towing vessels, and as retaining walls for soil erosion control. Costs for these applications will depend entirely on local conditions, and no generalized estimates are available at this time.

Another outlet is the reclaimed rubber industry, which uses scrap rubber in making compounds for manufacture of new tires and other rubber products. This industry consists of 12 facilities located primarily near tire manufacturers in Ohio and the Northwest. These facilities can draw tires from within a radius of 300 miles. Reclaiming plants are listed at the end of this section.

Short-Range Alternatives

These alternatives, landfilling and roadbuilding, involve some capital expenditure—from $2,000 to $100,000—for either tire splitting or shredding equipment (Tables 31 and 32).

Generally less expensive than tire shredders, tire slicing/cutting machines can be obtained for between $2,000 and $4,000. These machines generally require one man to operate and can process from 60 to 300 tires per hour. Sliced tires have been successfully landfilled: some size reduction is effected, which is advantageous not only for landfilling but also for transportation. Most tire slicers are portable and so can be taken to suppliers of tires, making possible significant savings in transportation costs of the tires. At the present time, there are only limited uses for sliced tires.

Portable tire shredders are relatively new to this country. Ranging in price from $5,000 to $100,000, several makes of tire shredders are currently available and more are in varying stages of development. Shredders enable landfill operators to efficiently dispose of tires. Even more than slicers, they make tires cheaper to transport for either disposal or reuse. It appears that economics will generally favor bringing the shredder to the tires rather than bringing whole tires to the shredder. Some concentration of tires would be required, however, making the portable shredder most applicable for use at retreaders' installations and tire collection points.

There is increasing interest in making use of shredded tires as an additive to asphalt for roadbuilding and repairing. However, most proven asphalt-additive applications require rubber particles smaller (minus 16 plus 25 mesh) than present shredder output. It is also necessary to remove any steel belt or bead material from the rubber used for roadbuilding. Therefore, for most roadbuilding applications rubber reclaimers are relied on for the supplies of shredded tires.

Information on the economics of operating tire slicers and shredders is sparse; costs will vary considerably with the number of tires processed and the availability of power-operated equipment to move and handle the tires. Most of the machines require one laborer full time just to load or operate the machine. Additional labor is required to maintain higher rates of tire processing.

Long-Range Alternatives

There are several relatively capital-intensive uses for scrap tires that are currently

TABLE 31

COSTS AND OPERATING PARAMETERS OF TIRE SLICERS AND SHREDDERS, 1974

Machine	Manufactured by	Price	Capacity (tires per hr) and tire type	Power requirements	Weight (lb)	Comments
Slicers:						
Ascot Tire Cutter	Parent Mfg. Co., Lewiston, Maine	$2,000–3,500	300, passenger and truck	110 V	1,500	Not rigged for road use
Branick	Branick Mfg., Fargo, N. Dak.	4,000	300, passenger and truck	220 V	1,000	Not rigged for road use
Shredders:						
Shred-Pax AZ-7	Teb Inc., Addison, Ill.	5,000	60, passenger	200 V 3-phase	800	Built in Germany, assembled in Illinois
AZ-15		8,500	60, passenger and light truck	200 V 3-phase	1,000	
AZ-20		19,000	300, passenger and truck	200 V 3-phase	*	
Tire Gator	Barclay/Noll Assoc., Burlingame, Calif.	75,000–90,000	1,000, passenger and truck	220/440 V 100 amp	*	1,000 tire/hr. capacity would require 3 men
Tire-Gon	Automotive-Industrial Marketing Corporation, Portland, Oreg.	30,000	125, passenger and small truck	220 V 3-phase	3,000	Price includes trailer ($2,600); operating cost assumes 1,000 tire/day operation
Tire Hawg	Metropolitan Disposal Corporation, Portland, Oreg.	52,500	400, passenger and truck	440 V 3-phase	24,000	Weight includes trailer for road use

* Not available.

TABLE 32

BREAKDOWN OF TIRE-GON OPERATING COSTS AT 7.5¢ PER TIRE, 1974 *

Item	Operating cost per month †
Labor	$600
Amortization	500
Maintenance	100
Power ($10/day)	200
Miscellaneous	80
Total	1,480 ‡

* Source: Manufacturer's data.

† No allowance has been made for transportation, dumping fee, revenue from sale of chips, or cost of capital.

‡ Cost per tire is 7.5¢ given 1,000 tires processed per day with 20 days per month operation.

under study by private and governmental organizations.

Destructive distillation and carbonization are two specific forms of pyrolysis—a controlled, oxygen-deficient heating process that decomposes organic substances. Tires are made up of carbon (83 percent), hydrogen (7 percent), and ash (6 percent), with trace quantities of nitrogen, oxygen, and sulfur. In pyrolysis, these constituents are yielded in the form of chemically complex oils and gases and a solid residue. The proportions of these yields vary according to the temperatures used in the process. The major product of high-temperature carbonization is carbon black, a major ingredient in synthetic rubber production. Destructive distillation, a lower temperature process, yields about 50 products—mainly gases but also oils (both light and heavy) and a dry high-carbon residue. This residue has a Btu value equivalent to coal but is relatively high in sulfur content

(1.5 percent). The economics for all of these processes are marginal, but recent trends in the energy field may stimulate their development.

Hydrogenization is a process of chemical synthesis in which the addition of hydrogen (the element which is removed from oil to make synthetic rubber) converts scrap rubber to chemicals from which new rubber can be synthesized. It is estimated that much more development of this process will be required before it will be economically competitive with traditional synthetic rubber production. Current fossil fuel cost escalations may well speed up the time when this process too will become economically viable.

Energy can be recovered from tires by shredding them and using them as supplemental fuel in conventional coal-fired installations or as the sole fuel in specially designed furnaces for industrial applications. The Btu value of tires is equal to or greater than that of coal. However, even the largest cities may not generate enough tires to sustain a power plant large enough to be commercially feasible at this time. Power requirements in this country could absorb the entire annual output of tires without affecting the demand for coal.

A pilot installation in England has used tires as fuel in specially designed furnaces to generate steam. Because of the combustion properties of tires, such a furnace would probably operate at about 30 percent efficiency—about half that of a comparable coal-fired furnace. However, even at this low efficiency, the pilot operation in England consumes 700 tires an hour, generating 3,500 pounds of steam per hour, and effects savings of about $110 per day over the cost of coal (the cheapest available conventional fuel).

It has been estimated that tire-fueled power could be competitive with gas- or oil-fueled power. The total estimated cost of generating power from tires is about $0.50 per million Btu. These costs include amortization of capital equipment and operating costs of storage, handling, preparation, and emissions control (50 percent higher than for coal) but *not* collection. Comparable costs for other fuel sources range between $0.60 per million Btu for gas and $0.75 for oil. These costs were calculated prior to 1973 price increases for petroleum products.

Goodyear is currently constructing a cyclone furnace for whole-tire incineration and steam generation at its plant in Jackson, Michigan. The furnace will cost $500,000 and was scheduled to commence operation in March 1974.

CONCLUSIONS

Although whole tires are difficult to dispose of using conventional techniques, new developments such as portable tire shredders now permit the sanitary landfilling of tires. Shredders offer a short-range solution to the problem of tire disposal.

Studies are now underway to develop long-range alternatives for the use of discarded tires and to expand present markets for reclaimed rubber. In addition, means of reducing the flow of tires into the solid waste stream, such as increasing the use of retreaded tires and promoting the consumption of longer wearing tires, are being explored.

RECLAIM PLANT LOCATIONS

A. Baker Manufacturing Company
South Bend, Indiana

Centrex Corporation
Findlay, Ohio

Eastern Rubber Reclaiming Company
Chester, Pennsylvania

Goodyear Tire and Rubber Company
Akron, Ohio

Laurie Rubber Reclaiming Company
New Brunswick, New Jersey

Midwest Rubber Reclaiming Company
East St. Louis, Illinois

Nearpara Rubber Company
Trenton, New Jersey

Uniroyal Chemical Division
Naugatuck, Connecticut

U.S. Rubber Reclaiming Company
Vicksburg, Mississippi

F. Perlman and Company
Memphis, Tennessee

Uniroyal Chemical Division
Ville D'Anjon, Quebec, Canada

Goodyear Tire and Rubber Company
Reclaim Division
Bowmanville, Ontario, Canada

Waste Lubricating Oil

Waste lubricating oil causes environmental problems to municipalities when it is disposed of in unacceptable ways such as uncontrolled burning as a fuel, which can result in the emission of lead and other heavy metals; uncontrolled dumping on land, which can result in the contamination of groundwater from leachate or contamination of waterways from runoff; and dumping in waterways, which can result in damage to fresh water and marine organisms.

Of the over 2 billion gallons of lubricating oils purchased annually in the United States, approximately 1 billion gallons are burned in the process of lubrication; 600 million gallons of waste oil are generated from automotive use and 500 million gallons from industrial, aviation, and miscellaneous applications (Table 33).

Of the known uses of waste oil, burning is most common; it accounts for approximately 500 million gallons. Use as road oil and in asphalt consume another 200 million gallons; 90 million gallons are re-refined into lube oil; and 300 million gallons are not accounted for. A significant portion of this latter quantity is probably burned as a fuel supplement during periods of conventional fuel shortages. The generation of waste oil appears to be increasing only slightly (1.3 percent annually) as longer cycle times between oil changes tend to offset the effect of increases in numbers of vehicles on the road.

COLLECTION

Waste oil is generally collected from service stations, garages, and commercial fleets by small, independent companies. There are approximately 1,500 of these collectors located in urban areas of the United States. They generally derive revenues from either a collection fee and/or from the sale of waste oil. The oil is sold generally to processors who prepare it for use as a fuel, to re-refiners

TABLE 33

CONSUMPTION OF LUBRICATION OILS, GENERATION OF WASTE OIL, AND USE OF WASTE OIL *
(In millions of gallons)

Consumption of lube oils:	
Automotive	1,100
Industrial and aviation	700
Other (including gov't)	400
Total	2,200
Generation of waste lube oils:	
Automotive	600
Industrial and aviation	400
Other	100
Total	1,100
Current uses of waste lube oils:	
Fuel (treated and untreated)	490
Re-refined for use as lube oil	90
Road oil and asphalt	200
Fate unknown	340 †
Total	1,100

* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Waste oil study; report to Congress, U.S. Environmental Protection Agency, April 1974. (Manuscript in preparation.)

† Includes 30 million gallons of re-refining wastes.

who make it reusable as lube oil to manufacturers of road oil or asphalt, or directly to users of fuel. If the prices of petroleum products are low, then economic factors encourage collectors to dispose of their cargo in the most expedient manner—dumping.

DISPOSITION

Use as a Fuel

The market for waste oil as a fuel, the major market for waste oil collectors, has two segments. The first is made up of waste oil processors who remove many of the contaminants in the waste oil prior to distributing it to users who mix it with conventional fuels. Some waste oil is distributed directly to users who mix the oil with conventional fuel without removing the contaminants. The contaminants will vary with the source of the waste oil and can include:

- Lead
- Copper
- Barium
- Zinc
- Phosphorus
- Tin
- Chromium

The most serious of these contaminants appears to be the lead in automobile waste oil. If this oil is burned undiluted, significant emissions of lead can result. Although mixing with other fuel oils can dilute these lead emissions considerably, the burning of unprocessed waste oil is not recommended unless sophisticated emission control equipment is employed.

Re-refining

Another market for waste oil is the re-refining industry, which in 1972 processed 90 million gallons of waste oil into lube oil. Although this industry has experienced a decline (in 1960, 300 million gallons were processed), recent price levels for petroleum products have improved the economics of re-refining. Most of the problems facing the expansion of this industry center around questions regarding product quality. Reservations about the quality of re-refined lubricating oil led to Federal labeling requirements and purchasing restrictions. As a result, re-refined lube oil is often ranked only with low-grade virgin lube oils. The economic disadvantages that result are compounded by an unfavorable tax treatment (IRS ruling 68–108). Under the terms of this ruling, re-refiners are required to pay a nonrefundable tax of 6 cents per gallon on virgin oils which are blended with re-refined oil and sold for off-highway use. A similar tax on lube oil composed completely of virgin oil and used off highways is refundable.

A typical re-refining operation consists of dewatering, treatment with acid to remove additives and impurities, mixing with clay to remove low-boiling components, blending with virgin stocks to improve viscosity and the use of additive packages to meet engine oil standards. The most serious environmental problem associated with re-refining is the disposal of the sludges and bottoms from the re-refining process. These wastes are generally highly acidic or contain high concentrations of heavy metals, primarily lead. These wastes can be satisfactorily disposed of in a properly managed landfill, one which prevents leaching of acids and heavy metals into groundwaters. The precautions recommended for the satisfactory landfilling of sludges and bottoms in EPA's "Effluent Guidelines and Standards" (1974) include the following:

> In order to ensure long-term protection of the environment from harmful constituents, special consideration of disposal sites should be made. All landfill sites should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geological considerations may not reasonably ensure this, adequate mechanical precautions (e.g., impervious liners) should be taken to ensure long-term protection of the environment. A program of routine periodic sampling and analysis of leachates is advisable. Where appropriate, the location of hazardous materials disposal sites should be permanently recorded in the appropriate office of legal jurisdiction.

Road Use

Use of waste oil for dust control on roads and in asphalt manufacture accounted for 200 million gallons of waste oil in 1972. Tests of the use of oil for dust control indicate that as much as 70 percent of the oil applied either migrates to the air on dust particles or onto adjoining lands and waterways through water runoff. The application of waste oil as a dust control measure should

TABLE 34

USES FOR WASTE LUBRICATION OIL *

Uses	Provisos
Re-refining for use as lube oil	Re-refining sludges and bottoms should be properly disposed of. Follow acceptable procedures for landfilling of sludges and bottoms.
Processing for use as fuel oil	Processor removes heavy metal contaminants (primarily lead) and processing bottoms are disposed of in an acceptable manner.
Burning untreated as a fuel	User employs sophisticated emission control equipment (including baghouses) to remove preventable lead emissions.
Spreading on roads for dust control	Oil use governed by ability of road surface to absorb oil, limiting significant migration on dust particles and oil runoff with water to adjacent areas.
Mixing with asphalt in road construction and repair	Process residuals containing concentrations of heavy metals should be disposed of in an acceptable manner.

* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Waste oil study; report to Congress, U.S. Environmental Protection Agency, April 1974. (Manuscript in preparation.)

therefore be carefully controlled, taking into account such elements as the type of road surface, the amount of oil applied, and the type of vegetation near the road being oiled. When used in the manufacture of asphalt, waste oil can cause significant increases in emissions into the air. These emissions represent a potential hazard if they contain significant quantities of lead or other heavy metals.

Land Spreading

Many petroleum refineries currently disperse of oily wastes by a technique known as land spreading. If deep, fine-textured soils are selected for this practice, then limited amounts of oil will adhere to the soil and groundwater contamination can be avoided. However, indiscriminate dumping of oil on coarse, porous, or shallow soils is likely to result in water pollution. Although under certain carefully controlled conditions land spreading may be environmentally acceptable, it represents an extremely inefficient utilization of a nonrenewable resource.

CONCLUSIONS

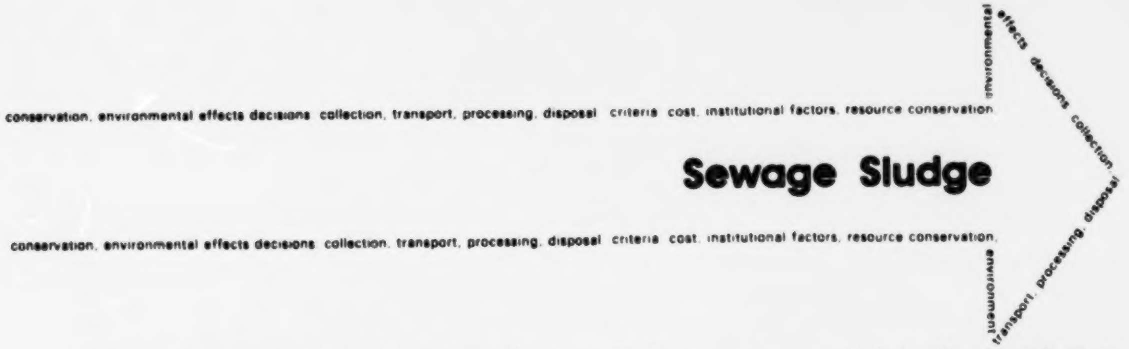
Cities and municipalities should identify quantities and sources of waste oil generation.

Collectors of waste oil should also be identified as well as forms of disposition of the waste oil.

All methods of disposition of waste oil should be controlled to avoid unfavorable environmental effects (Table 34).

In order to control the collection and disposition of waste oil, communities should issue appropriate laws and ordinances that:

- make dumping into watercourses illegal.
- require a permit for the operation of a facility to process or dispose of waste oil.
- require a permit for the collection of waste oil.
- require that all major waste oil generators contract with certified collectors for the hauling of this product.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conservation, environmental effects decisions collection, transport, processing, disposal criteria cost, institutional factors, resource conservation
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Sewage Sludge

Disposal of residual solids generated by municipal wastewater treatment plants is a serious problem facing the wastewater treatment authorities. Strong national emphasis has been placed on clean wastewater treatment effluents and clean receiving streams with little regard for the problem of what to do with the large quantities of sludge generated by wastewater treatment.

The quantity of sludge generated is dependent on the type of wastewater treatment process used and the degree to which it is applied. Implementation of secondary and tertiary treatment requirements will result in dramatic increases in sludge quantities in the next 10 years. In some cases, the selection of a sludge utilization or disposal method is strictly dependent upon the wastewater processing technique used. In nearly every case, however, there is a potential for environmental degradation as a result of the concentration of pathogenic organisms and toxic chemicals in the sludge. In addition to the environmental considerations, there are legal and economic considerations involved in the sludge disposal problem.

ALTERNATIVES

Ocean Disposal

Sewage sludge is still deposited in the ocean by coastal cities, using either a pipeline or barges. The continued use of this disposal method is in doubt as a result of more stringent water pollution control laws.

Utilization on Land

There are several techniques available for utilization of sewage sludge as a soil conditioner and low-grade fertilizer. Sludge application to crop and forest land to replenish depleted soil and to strip-mined land to restore soil fertility has been widely practiced throughout the United States and Europe. Sludge may be applied in the liquid state (most popular technique), in the dewatered form (approximately 75 percent water), or dry.

Sanitary Landfill

There are two variations of subsurface land disposal of sewage sludge, namely, with or without mixed municipal solid waste.

For disposal with mixed municipal solid waste, dewatered, digested sewage sludge is placed on the working face in a sanitary landfill and promptly covered with earth or municipal refuse. Opinion is mixed as to the need for digestion and dewatering of sewage sludge prior to incorporation in a sanitary landfill.

While not widely practiced, it is possible to operate a sanitary landfill for sludge disposal alone. In this case, sewage sludge would at a minimum require dewatering prior to placement in a landfill.

Thermal Processing

While incineration of sewage sludge or solid waste is often considered a disposal alternative, it is, in fact, only a volume reduction technique. Combustion or thermal processing of sewage sludge includes heat drying, pyrolysis, and use of sludge as supplementary fuel, in addition to incineration.

Heat drying is a processing technique which may be used prior to sludge utilization on land. Heat drying provides the sterilization necessary for use of sludge as either a low-grade or fortified fertilizer. Some degree of heat drying may also be utilized prior to incineration, pyrolysis, or use of the sludge as supplementary fuel.

ADVANTAGES AND DISADVANTAGES

Ocean Disposal

The main advantage of this alternative is the low overall cost resulting from limited sludge treatment and dewatering requirements and cheap pipeline or barge transportation. The main disadvantage is the environmental and aesthetic degradation of coastal waters which may result from this practice.

Utilization on Land

The advantage of this alternative is that an inexpensive soil conditioner and fertilizer is made available. One disadvantage is that large amounts of land are required for this alternative. Application rates of 10–25 tons of sludge solids per acre per year are typical but depend upon soil type, climatological conditions, type of crop or vegetation, application technique, and whether the sludge is liquid, dewatered, or dry.

There are two additional disadvantages in land utilization of sludge. The most obvious is the potential for ground and surface water degradation from infiltration and run-off of sludge contaminants, both biological and chemical. Proper selection, design, and operation of the sludge utilization site can keep the potential for degradation to a minimum. A site monitoring program is required, however.

The other disadvantage involves the type of crop grown on the sludge utilization site. The presence of chemical and biological contaminants in the sludge, especially heavy metals and pathogenic organisms, restricts both the type and intended use of crops. High concentrations of certain chemicals result in plant toxicity and reduce crop yield. Plant uptake of heavy metals, especially arsenic, cadmium, lead, mercury, and selenium, and pathogenic organisms on the surface of plants may make the crops unfit for human consumption.

Sanitary Landfill

The advantage of this alternative is that sanitary landfills are usually available in or around most metropolitan areas and the high paper content of municipal solid waste is able to absorb some of the moisture in the sludge. The disadvantage of this disposal method is that it may increase the potential for pollution of ground and surface water by leachate and present safety hazards from methane gas formation. Operational problems may also result from inclusion of sewage sludge in sanitary landfills, such as adaptability of equipment, site operator objections, and unsightly conditions.

Critical attention must be devoted to site selection, engineering design, leachate and gas control monitoring systems, and operating plan development for any sanitary landfill receiving sewage sludge.

Very few advantages exist for operating a landfill solely for sludge disposal unless its close proximity to the sewage treatment plant reduces transportation costs to near zero. The establishment of a landfill only for sludge results in an unnecessary duplication of land disposal sites, and solves none of the potential problems in a combined sludge/solid waste sanitary landfill. In fact operational problems may be aggravated by the absence of the absorptive and bearing capacities of mixed municipal refuse.

Thermal Processing

When sludge is processed for use in a pyrolysis unit or as supplementary boiler fuel, it must be dewatered. In order to evaluate the feasibility of using dewatered sludge as a fuel source, the available heat content of the sludge must be determined. Dry sludge solids have a relatively high heat value; however, considerable heat is required to drive off the water in the sludge and to bring the sludge to the combustion point.

Since each of the combustion processing alternatives requires the use of substantial quantities of auxiliary fuels which may be very expensive and of limited availability, an economic analysis, including an energy balance, must be performed prior to selection of any combustion processing alternative for sewage sludge.

The potential air pollution from thermal processing of sewage sludge is also a serious disadvantage.

CONCLUSIONS

The Office of Solid Waste Management Programs is currently supporting a demonstration project involving liquid digested sewage sludge disposal in a sanitary landfill at Oceanside, California. The results of this demonstration will be published at the completion of the project and should enable an evaluation of the acceptability of this sludge disposal technique. Until additional experience and information is available on other landfill options it is advisable to landfill only properly digested and dewatered sewage sludge in a well designed and operated solid waste sanitary landfill.

Application of sludge on the land as a fertilizer also has potential dangers which are under investigation. The Food and Drug Administration has not yet established acceptable concentrations of heavy metals for all food crops. At least until such time as standards are established, only crops *not* in the human food chain should be grown on soil to which sewage sludge has been applied.

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

APPENDICES

criteria: cost, institutional factors, resource conservation, environmental effects decisions: collection, transport, processing, disposal

conservation environmental effects decisions collection transport processing disposal criteria cost institutional factors resource conservation

Appendix A
Residential Collection Management Tools

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This appendix describes three tools that EPA has developed to help managers evaluate and improve the efficiency of their residential collection systems. These tools are:

Collection Management Information System (COLMIS)
Route balancing procedure
Heuristic routing technique

MANAGEMENT INFORMATION SYSTEMS

The basis of effective management and decision-making is the availability of reliable information on the system being managed. While lack of information can lead to loss of control, good information can serve as the basis for improvements and cost savings.

Solid waste management needs definitive information on the operational aspects of collection and the costs involved in providing this service. This information should provide the answers to such key questions as:

- What are the actual collection costs per home and per ton?
- How much waste is collected per home per week? How does this vary seasonally?
- How many homes are collected per crew per collection hour?
- Which are the most productive and least productive crews?
- How are productivity and costs affected by different collection frequencies, crew sizes, equipment types, and storage devices?
- How effectively are the equipment capacities being utilized? What is their density capability?
- How many homes constitute a load for different generation rates?
- What are equipment operating costs? When should equipment be replaced?

A good method of obtaining the required information is through the use of a computerized reporting system. One such system is COLMIS, Collection Management Information System, available from EPA at no charge. This system generates reports with different levels of detail for the various levels of management.

There are three basic reports which the COLMIS system generates on a weekly basis. Each of these reports includes daily data for each route plus a weekly average and a year to date average. The following lists the data included in each of the basic reports.

Route Information Report

- Motor pool to route—time and miles per day
- Collection operation—time and miles per day
- Transport operation—time and miles per day
- Total time to route, collect, and transport—hours
- Downtime—hours
- Lunchtime—hours
- Weight per day—pounds and tons

Collection Information Report

- Homes served per collection day
- Weight in pounds per collection day
- Persons served per collection day
- Generation rate per person per day—pounds
- Collection time per home—minutes
- Collection time per 100 pounds—minutes
- Collection time as percent of total time worked
- Total time worked as percent of standard time
- Loads per day to incinerator, landfill, or transfer station

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- Weight per cubic yard of first load—pounds

Collection Cost Information in Dollars

- Cost from motor pool to route
- Cost of collection operation
- Cost of transport operation
- Equipment costs
- Manpower costs
- Total costs
- Costs of manpower during equipment down periods
- Incentive costs
- Overtime costs
- Cost per ton
- Cost per home—per week, per year

While serving as a creditable record of operations and costs, these reports are a valuable planning tool. Information from these reports can be used to evaluate the present system and to design new systems. They provide the specific data needed to determine a "fair day's work" for each crew, truck and crew requirements for the entire city, boundaries for daily routes and districts, and costs of operation. They can also aid in determining the useful life for equipment and thus help in planning a capital replacement program.

Cost Effectiveness

Effective use of this type of analysis can lead to significant results. Fourteen of the 35 communities in which the COLMIS program has been installed are in the same regional authority in Michigan, the Southeast Oakland County Incinerator Authority, which serves a population of 360,000. Management information from COLMIS and assistance from the authority and EPA in routing and evaluating crew sizes, equipment types, and collection methodologies have enabled these communities to maintain the same level of service (once-per-week, curbside) while cutting direct collection costs by 16.7 percent (within a 6-month period) plus a demonstrated potential reduction of another 21 percent if all the communities and routes are converted to the most efficient system which has been identified. Part of this savings was due to the competitive situation created among the crews and among communities because the performance of each crew and system was documented by COLMIS. Five of the systems are run by private contractors who are becoming a part of this competitive situation between communities and improving their efficiency, as evidenced by the fact that all new contracts are either below or at the same cost as the previous contracts.

The cost effectiveness of COLMIS can be seen by comparing its costs to the savings achieved. The total computer cost, including keypunching, for processing the data for this 360,000 population is $5,200 per year, a 1.4 cents per person per year investment with a resultant savings of 73 cents per person per year.

ROUTE BALANCING

Route balancing is the process of determining the optimum number of services that constitute a fair day's work and dividing the collection task among the crews so that all have equal workloads. Route balancing can have any of the following objectives: (1) to estimate the number of men and trucks required to collect waste in a new or revised solid waste system, (2) to aid in developing or evaluating a bid price for a collection contract, (3) to aid in evaluating the performance of the collection crews, as a whole or individually, (4) to establish a work standard to be used in a task system, in which the crews may go home when their predetermined tasks are completed for the day, or in a wage incentive system, in which the crews are rewarded by financial bonuses for any increases in productivity over a prescribed standard or over previous period performances, or (5) to balance or equalize the workloads among collection crews.

Route balancing is necessary if a new collection system is being instituted, or a major change in the present system, e.g., backyard to curbside collection, is going to take place, or if a collection contract is up for bid. Route balancing should also be conducted if crew performances have never been evaluated or need reevaluation, if the present routes are not balanced, or if the present routes do not provide a fair day's work for the crews.

A fair day's work is determined and routes are balanced by analyzing each component of time in the collection day, that is, how the crew spends its time.

Adding the component times of a collection day results in an equation for the total time in the workday (Y):

$$Y = a + b + n(c_1 + c_2 + d) - c_1 + e + f + g$$

where a = time from garage to route
b = total collection time on route
c_1 = time from route to disposal site
c_2 = time from disposal site to route
d = time at disposal site
e = time from disposal site to garage
f = time for official breaks
g = slack time: lost time due to breakdowns and other delays, lunchtime, and incentive time
n = number of loads

This equation is the basis of the analysis for a fair day's work and route balancing.

The data required for this analysis are: (1) time and distance data related to the components of the collection day, (2) the number of services by type and where they are located, and (3) the amount of waste generated per service, including seasonal variations, and (4) basic equipment and labor costs.

One method for gathering this data is by using COLMIS as already discussed. Values for each time variable are readily obtainable for any existing system from the COLMIS reports or other records. Values for each of these time elements for each route may be compared to ascertain their reasonableness.

In designing a new collection system it is necessary to determine the appropriate number of services per crew per day, which tells how many trucks and men are required. The steps required are:

(1) Add variables a, e, f, and g, and subtract c_1. These variables are readily obtainable from the existing system.

(2) Add variables $c_1 + c_2 + d$ (round-trip haul and dump time for one load) for specific route areas, which are also available from the existing system.

(3) Select the equipment type and size, and crew size.

(4) Determine the number of services per load (N):

$$N = \frac{\left(\begin{array}{c}\text{Vehicle capacity}\\ \text{(cu yd)}\end{array}\right)\left(\begin{array}{c}\text{Waste density capability}\\ \text{lb/cu yd)}\end{array}\right)}{\text{Generation rate (lb/home/wk)}}$$

(5) Determine the collection time per service through obtaining statistics (such as COLMIS data) from other communities which have similar systems and good labor productivity or by conducting an experiment on one of the existing routes.

(6) Determine how much time it takes to collect one load by multiplying the results of steps 4 and 5.

(7) Set the total day equal to the number of hours the collectors are to work, e.g., 8 hours.

(8) Add the times from steps 1, 2, and 6 and compare to step 7.

(9) Add steps 2 and 6 to step 8 and compare again to step 7. Repeat this until the total time is close to the total day value selected in step 7.

(10) Calculate the number of trucks required to serve the community.

$$\begin{array}{c}\text{Trucks}\\ \text{required}\end{array} = \frac{\left(\begin{array}{c}\text{Total No.}\\ \text{services}\end{array}\right)\left(\begin{array}{c}\text{Collection frequency}\\ \text{per week}\end{array}\right)}{\left(\begin{array}{c}\text{Services per}\\ \text{truck per day}\end{array}\right)\left(\begin{array}{c}\text{No. workdays}\\ \text{per week}\end{array}\right)}$$

In this equation, the value of services per truck per day is a function of frequency of collection and point of collection (curb or backyard) and is the value calculated in step 9 based on on-route versus transport time.

(11) Calculate the cost of a crew and truck

Vehicle cost = depreciation
+ maintenance
+ consumables
+ overhead
+ license fees and insurance

Labor cost = salary of driver
+ salary of collector(s)
+ fringe benefits
+ indirect labor
+ supplies (e.g., gloves)
+ administrative overhead

Total cost = vehicle cost and labor cost

(12) Multiply cost per crew by the number of crews needed, to get total system cost.

(13) Divide cost per vehicle by number of customers the truck can serve per week to find the cost per customer.

(14) Evaluate the effects of peak and low generation periods by performing the calculations for steps 1 through 6 using data from these periods.

(15) Repeat steps 1 through 7 for any other system that could provide the service. Some figures such as time per stop and vehicle costs may have to be obtained from other sources.

(16) Comparison of total cost and cost per customer for each system examined helps give a picture of relative degrees of efficiency. The choice may be to pick a system different from the present one. Or it may be shown that level-of-service or other policies should be reconsidered.

HEURISTIC ROUTING

Routing is the process of determining the path or route the collection vehicle is to follow as it collects waste from each service in a specific area. The objective is to minimize the noncollection distance, e.g., streets with no services or repeat streets, and delay times, e.g., U-turns, rush hour traffic, and left turns, for each collection vehicle.

EPA has developed a "heuristic" routing technique that can be applied by the collection system supervisory personnel without the use of computers or a consultant. The heuristic technique is based on applying some common-sense rules of thumb in conjunction with specific routing patterns. The major rules of thumb are:

(1) Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.

(2) Total collection plus haul time should be reasonably constant for each route in the community, i.e., workloads should be equal.

(3) The collection route should be started as close to the garage or motor pool as possible, taking into account heavily traveled streets, route elevations, and possible patterns (see rules 4, 6, and 9).

(4) Heavily traveled streets should not be collected during rush hours.

(5) Services on dead-end streets can be considered as services on the street segment that they intersect since they can only be collected by passing down that street segment. To keep left turns at a minimum, collect the dead-end streets when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.

(6) When practical, steep hills should be collected on both sides of the street while the vehicle is moving downhill for safety, ease, and speed of collection, to reduce vehicle wear, and to conserve gas and oil. Higher elevations should be at the start of the route.

(7) For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks and to collect waste when it is to the right of the vehicle.

(8) For collection from both sides of the street at the same time, it is generally best to route with long straight paths across the grid before looping clockwise.

(9) For specific block configurations within the route, routing patterns should be applied. (Specific routing patterns are available in the second and fourth references below.)

Once the number of services for each route has been determined through route balancing analysis, routing can be performed. All the data required for routing can be recorded on community maps. This data includes: (1) the number of each type of service on each side of each street segment, (2) all one-way, dead-end, and heavily traveled streets, (3) corner-lot residents, and (4) streets that should be collected one side at a time.

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Appendix B
Collection Costs and Productivity

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environmental effects decisions collection disposal processing transport environment

The cost and productivity tradeoffs faced by a city official or private contractor in operating a collection system are complex. Preceding papers have attempted to deal with subsets of these tradeoffs on an issue-by-issue basis, e.g., point of pickup comparisons can be made by holding all other variables constant and comparing the difference in cost between curbside and backyard collection. This appendix discusses overall collection cost factors, ranges of cost elements that appear to be reasonable, and the interim results of a study of costs and productivity of systems in 11 cities.

OVERALL COLLECTION COST FACTORS

There are eight key cost factors which should be examined for every collection operation.

Equipment:
- Depreciated vehicle procurement cost
- Maintenance cost
- Consumable items
- Miscellaneous costs (e.g., insurance, license fees, etc.)

Labor:
- Wages
- Fringe benefits

Overhead:
- Management and administrative overhead
- Office and garage rental, utilities, and supplies, etc.

While it is difficult to make national estimates of these costs because of wide variations, broad ranges can be determined which can give some guidance to managers.

RANGES OF COST ELEMENTS

The typical annual costs for two- and three-man crews working with a 20-cubic-yard rear-loading vehicle have been estimated (Table 35).

TABLE 35

COLLECTION COSTS FOR TWO- AND THREE-MAN CREWS, 1973

Cost elements	2-man crew	3-man crew
Depreciated vehicle procurement cost *	$4,800	$4,800
Maintenance cost	2,000	2,000
Consumable items	1,675	1,675
Miscellaneous (insurance, fees)	1,200	1,200
Wages †	12,000–24,000	18,000–36,000
Fringe benefits (18 percent of direct labor)	2,160–4 320	3,240–6,480
Management and administrative overhead (13 percent of direct labor)	1,560–3,120	2,340–4,680
Overtime ‡	1,200–2,400	1,350–2,700
Total cost	26,595–43,515	34,605–59,535

* Straight-line depreciation over 5 years.

† Men paid from $6,000 to $12,000 per year.

‡ Calculated at 10 percent of direct labor for 2-man crews and 7½ percent for 3-man crews.

Clearly, labor costs (including fringe benefits) account for the largest portion of total collection costs (72 to 84 percent). Using these and similar sample figures, collection operating officials can begin to identify deviations in their costs. Clearly, many of the standard factors, e.g., 18 percent for fringe benefits or 13 percent for management and administrative overhead, vary from city to city. Each city should derive its own numbers for these cost factors where possible.

Collection cost per ton and collection cost per service per year are other useful indexes because they relate costs to a productivity measure. Since cost per ton is the ratio normally used to express processing and disposal costs, collection cost per ton is useful in calculating the overall collection, processing, and disposal costs for a system. Cost or price per ton is also the measure used for quoting the market value of reclaimed materials. Thus, the additional collection and processing costs per ton for a reclamation program can be readily compared to the revenues per ton from recycled materials and savings per ton in disposal. The cost per service per year ratio is a more meaningful figure to the homeowner since it tells him how much solid waste collection and disposal are costing him.

COST AND PRODUCTIVITY STUDY

Cost constitutes only half of the decision-making factors in evaluating a collection system. Productivity is the other side of the ledger, and an operating manager must attempt to balance the two sides.

Several indexes have been developed to show system productivity. Some of these are: services/day/truck, services/man/hour, tons/day/truck, and tons/man/hour. As can be seen from these measures, crew size, tonnage collected, and time to collect are elements in achieving high productivity.

Interim results are available of a study comparing the productivity and costs of nine curbside and two backyard systems with different equipment types and crew sizes (Table 36). Overall, three-man crews proved to have a significantly higher cost. Both the cost/home/year figures and cost/ton figures should be examined since the average weight per service directly affects the number of services a crew can collect.

The data for the study was obtained from the EPA Data Acquisition and Analysis Program (DAAP) and from time-and-motion study information from systems in various parts of the country. The DAAP is similar to COLMIS (see Appendix A). The figures shown in Table 36 represent the average values for four different routes for each system. The DAAP information represents data collected each working day for each route for a full year. The time-and-motion study information represents data collected for 1 day for each crew for each quarter of the year. The first column presents data from Utah; the second, from California; the third, Michigan; the fourth, Illinois; the fifth, Rhode Island; the sixth, Illinois; the seventh and eighth, Arizona; the ninth, Florida; the tenth, California; and the eleventh, Wisconsin.

The first section of the table describes the systems being evaluated. The next section shows on a percentage basis how the total man-hours of the crew are distributed among activities. Next is a summary of how much of the crew time is spent on productive activities: those activities which must be performed to pick up the waste and haul it away. Transport, for example, is productive time for the driver but not for the collectors, which penalizes the larger crew sizes. Collecting, driving, riding, walking, and compaction times are considered as productive times. Waiting and other time are nonproductive.

Since many variables affect crew performance, the next section is provided to enable better comparisons. For example, an important determinant of collection time for curbside pickup is the percent of one-way storage (bags and miscellaneous) items versus cans.

The next section shows how productive the crews are on the route in terms of services per man-hour and tons per man-hour. These two variables must be considered jointly, although the amount of waste tends to be the major time determinant.

The last section shows costs on a service and tonnage basis.

In order to enable a better comparison be-

TABLE 36

PRODUCTIVITY AND COST ANALYSIS FOR RESIDENTIAL COLLECTION SYSTEMS, 1973 *

Characteristics	Collection policies and methodologies										
	Curb-alley systems									Backyard systems	
System number	1	2	3	4	5	6	7	8	9	10	11
Collections per week	1	1	1	1	1	1	2	2	2	1	1
Crew size	1	1	2	2	3	3	1	2	3	2	2
Incentive system	Task	8 hr	Task	8 hr	Task	8 hr	Task	Task	Task	Task	8 hr
Collection patterns	One side	One side	One side	One side	Both sides	Both sides	One side	One side	Both sides	Tote barrel	Tote barrel
Vehicle size (cu yd) and type †	25 SL	25 SL	20 RL	25 RL	20 RL	25 RL	33 SL	8 SL	20 RL	20 RL	13 RL
	Percent of total crew time spent on various collection activities										
Transport	34.8	32.2	31.5	30.2	24.2	35.4	22.6	27.2	30.0	18.3	20.6
On route:											
Driving	17.9	13.5	8.9	12.2	5.8	3.1	24.7	10.0	7.2	‡	‡
Riding/walking §	0	0	7.8	11.6	11.8	5.8	0.2	18.1	14.5	‡	‡
Collecting	45.8	51.5	30.6	19.5	35.7	38.2	50.1	27.8	29.3	81.7	79.4
Waiting (including compaction) ¶	0.8	1.8	20.8	26.8	22.2	17.3	1.1	6.5	18.5	‡	‡
Other ¶	0.7	1.0	0.4	0.2	0.3	0.4	1.3	10.4	0.5	‡	‡
Total productive time	98.5	97.2	63.0	58.3	61.3	58.7	97.6	69.5	61.0	‡	‡
	Route characteristics (daily averages)										
Pounds per home per collection	46.2	71.0	49.3	50.5	62.2	64.9	28.2	24.4	33.1	33.9	51.1
Number of bags per home per collection	1.5	1.3	2.6	4.6	3.6	1.5	0.9	0.5	1.2	0.0	1.4
Number of cans per home per collection	2.3	2.7	1.3	0.4	1.7	2.7	1.6	1.5	1.1	1.2	2.4
Number of miscellaneous items per home per collection	0.7	1.1	0.7	0.5	1.0	1.7	0.5	0.5	0.4	0.0	0.5
Collection miles per day	10.5	6.1	10.1	13.1	10.5	4.5	13.7	20.5	10.4	6.9	6.6
Transport miles per day	46.1	18.8	32.6	29.9	14.3	34.4	22.2	12.0	33.4	6.0	17.6
Collection hours per day	3.8	4.6	4.8	4.7	3.9	4.9	4.9	4.1	4.4	5.1	5.5
Transport hours per day	1.7	2.0	1.9	1.8	1.0	2.5	1.1	1.4	1.6	1.0	1.2
Hours worked per day	5.9	6.7	7.0	6.7	5.2	7.6	6.3	5.7	6.3	6.2	6.9
Loads per day	1.8	1.6	2.4	1.9	2.2	1.6	1.0	4.4	2.3	1.0	1.9
Services per day	410	254	512	575	407	306	410	574	854	364	243
Tons per day	9.4	9.0	12.6	14.5	12.6	9.7	5.7	7.0	14.1	6.2	6.2
	On-route productivity										
Services per crew per collection hour	107.3	55.7	107.0	123.3	101.5	62.7	84.2	138.4	200.5	72.1	44.4
Tons per crew per collection hour	2.5	2.0	2.6	3.1	3.3	2.0	1.2	1.7	3.3	1.2	1.1
Services per crewman per collection hour	107.3	55.7	53.4	57.7	34.9	20.9	84.2	66.6	66.5	35.3	22.1
Tons per crewman per collection hour	2.5	2.0	1.3	1.5	1.1	0.7	1.2	0.8	1.1	0.6	0.6
	Cost efficiency **										
Total cost per home per year	9.88	15.60	11.96	11.44	20.28	28.60	19.24	26.52	24.96	16.64	24.44
Total cost per ton	8.29	8.46	9.53	8.72	12.82	17.13	13.48	21.15	14.67	19.26	18.41

* Source: ACT SYSTEMS, INC. Unpublished data.
† RL, rear loader; SL, side loader.
‡ Not available.
§ Driving, riding for one-man crews.
¶ Nonproductive time.
** Costs have been normalized across all 11 systems to permit intersystem comparisons, therefore, these figures do not reflect actual collection costs.

tween equipment types and crew sizes, all the basic cost figures were normalized by using the average values for the 11 cities being evaluated. For example, the procurement costs of the collection vehicles were based on average prices paid, in 1972 dollars (Table 37). The depreciation used was straight line over 5 years. Maintenance cost for the first year was 0.055 multiplied by the initial cost of the vehicle. The consumable cost was actual fuel and oil consumption multiplied by $0.17 per gallon for fuel and $0.23 per quart for engine oil. Wages in dollars per hour were $4.34 for drivers and $4.15 for collectors. Fringe benefits were 18.3 percent of wages. Personnel overhead was 13.1 percent of wages. The overtime factor was 1.5 multiplied by the hourly wage for drivers and collectors, and insurance and fees were $100 per month per vehicle.

TABLE 37

PROCUREMENT COST OF REAR-LOADING AND SIDE-LOADING COLLECTION VEHICLES, 1972 *

Capacity (cu yd)	Side loader	Rear loader
8	$14,900	
13		$15,900
16		16,700
18		17,000
20		22,700
25	23,900	23,900
33	30,000	

* Source: ACT SYSTEMS, INC. Unpublished data.

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Appendix C
Closing Open Dumps

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Governmental agencies, industry, citizens, and environmental groups should all be considered in developing a plan to eliminate a dump and to establish an acceptable substitute. The plan should provide for informing everyone about the need for closing the dump and the procedures that will be followed. The plan should also outline the funding arrangements necessary to carry out the operation and the anticipated use of the closed site. It is often more feasible to convert the dump into a sanitary landfill than to establish a new site.

INFORMATION DISSEMINATION

It is imperative that the public, industry, and municipal agencies be kept informed of activities pertaining to the dump closing. They are the source of the necessary funds and their cooperation is critical to a satisfactory solid waste disposal program. They should, therefore, be told:

- Why the dump is being closed
- How the job will be done
- What method of acceptable waste disposal will replace the dump
- What the costs are

A vigorous public information program is essential to success, and all the various techniques of information dissemination can be used to help win a favorable press. Keeping the public informed should begin when the planning starts and continue with progress reports until the dump is closed and the new disposal method is operating successfully.

DISPOSAL DURING AND AFTER CLOSURE

A dump cannot be closed in 1 day. The rat extermination program alone normally requires up to 2 weeks, and extinguishing fires may take another week. Compacting and covering may take over 2 months, depending upon the size of the dump.

Open dumping must stop before rat extermination starts, and only authorized personnel should be allowed on the site during the closing operation. An approved alternative, with fixed and posted hours of operation, must be established for the wastes formerly disposed of at the dump.

RAT EXTERMINATION

Rat extermination must be given special attention when closing an active dump. At an old open dump where the food source has been exhausted, rats and insects are unlikely to be present. Where there is a nearby food source, the old dump may still be used by rats for harborage. It is necessary, therefore, to establish conclusively the absence of rats. If rats are present, an extermination program must be conducted. If the dump-closing operation is improperly conducted, the rat problem may be compounded.

Rats are potential carriers of numerous diseases; if they are not killed when a dump is closed, they may pose even more of a problem than when they are at the dump. They may migrate in numbers to populated areas in search of food and harborage. At a minimum, this would cause unfavorable reaction to the dump closing, and the situation would worsen if there were a rise in the incidence of rat bites.

Only trained personnel should be allowed to conduct the operations since the improper use of poisons is dangerous. The work is best done by a pest control specialist or by a government rodent control expert. Assistance may be obtained from State and local health officials, pest control services, the U.S. Fish and Wildlife Service, the Bureau of Community Environmental Management of the U.S. Public Health Service, or the Office of Solid Waste Management Programs.

EXTINGUISHING FIRES

Fires at dumps may be difficult and expensive to extinguish. In some cases the burning solid waste may have to be exposed and spread out, requiring the use of heavy earth-moving equipment. The operator must work very carefully to prevent injuring himself or damaging his equipment. Spreading the waste generally allows the fire to partially burn itself out, and water can then be applied to the smoldering remains. Caution must be exercised to avoid causing water pollution through use of excessive quantities of water. Fires can usually be extinguished while the rat poisoning program is underway.

COVERING THE DUMP

Immediately following the rat poisoning and fire extinguishing, the dump surface should be graded, compacted, and covered with at least 2 feet of soil. In closing large dumps, the rat extermination program should be maintained while successive sections of the dump are covered. To grade, compact, and cover most dumps, large crawler dozers will be necessary. Either the trench or the area method is generally used in closing the dump.

In the trench method, wastes are spread in thin layers in an excavation, compacted, and then covered with the excavated soil (Figure 8). This achieves maximum density and minimum settlement. The cover material should be compacted to keep flies in and rats out, and it should be graded to keep surface water from ponding. The bottom of the

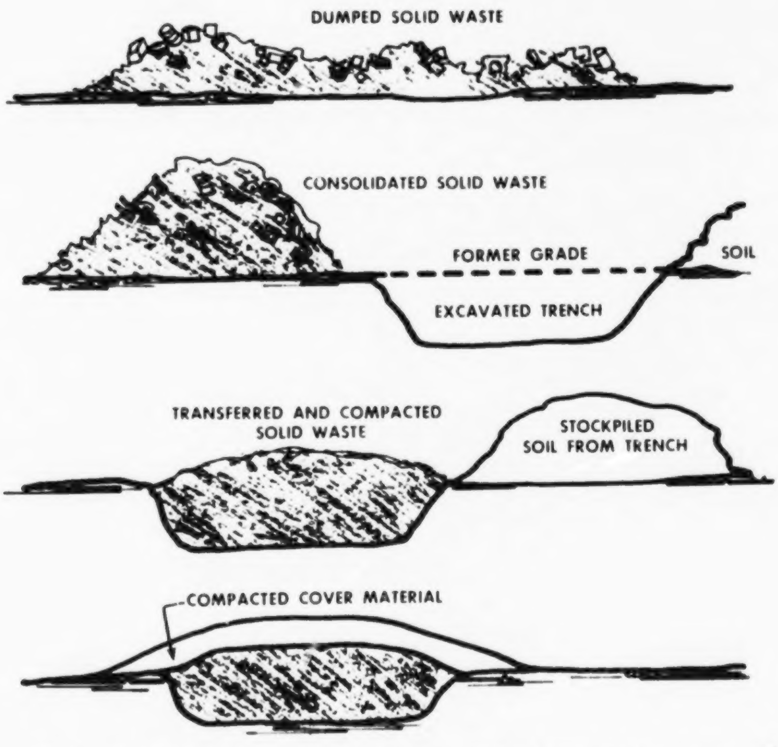

FIGURE 8. With the trench method of covering a dump, wastes are spread in a thin layer in an excavation, compacted, and then covered with the excavated soil, compacted, and graded. Source: BRUNNER, D. R., S. J. HUBBARD, D. J. KELLER, and J. L. NEWTON. Closing open dumps. Washington, U.S. Government Printing Office, 1971. 19 p.

trench should be kept above the level of high groundwater.

The area method also involves spreading the wastes in thin layers, compacting it, and then covering it with a minimum of 2 feet of compacted soil (Figure 9). If the solid waste is spread over a large area, it must be consolidated and compacted to reduce the amount of settlement and cover material required. The cover material must be graded to avoid ponding of surface water.

PROTECTION OF WATER QUALITY

If the dump is in a marshland or an area where the groundwater or surface waters have been contaminated, remedial action should be taken by removing the solid waste from the water or treating the water. The latter step is normally not feasible because of the difficulty in collecting and treating contaminated water. The solid waste and water can be separated by diverting the flow of water or by removing the solid waste from the watercourse. If necessary, surface streams may be relocated and the groundwater level lowered, but it is often more economical to remove the solid waste from the stream using draglines.

COVER MATERIAL

Cover material should be selected according to its ability to limit the access of vectors to the solid waste, control moisture entering the fill, control the movement of gas from the decomposing waste, provide a pleasing appearance, control blowing paper, and support vegetation.

Not all soil types perform these functions equally well. While the soil is usually selected from the types available nearby, consideration needs to be given to its suitability before using it as cover material.

The depth of the cover material depends on the use planned for the closed dump and the soil type. Usually 2 feet of earth is sufficient, and it should be compacted and graded to a slope of 2 percent or greater. Proper grading is important since it prevents excessive soil erosion and ponding. Ponding tends to infiltrate and saturate the fill, resulting in water pollution.

To further reduce erosion, the area should be seeded with grass or other vegetation.

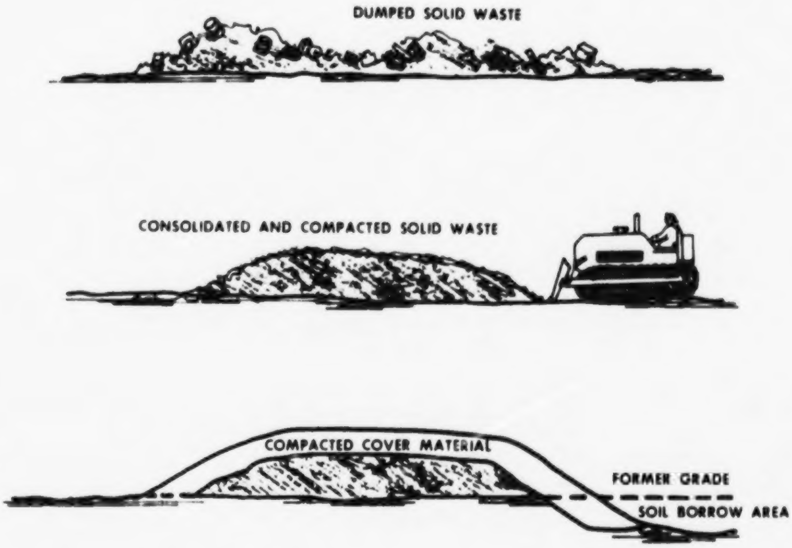

FIGURE 9. With the area method of covering a dump, wastes are spread in thin layers, compacted, and covered with a minimum of 2 feet of compacted soil. Source: BRUNNER, D. R., S. J. HUBBARD, D. J. KELLER, and J. L. NEWTON. Closing open dumps, Washington, U.S. Government Printing Office, 1971. 19 p.

Two feet of soil is usually sufficient for grass, but more is necessary for shrubs and trees. If the dump is along a lake front or the edge of a stream, riprap is often required to prevent water from eroding the edge of the cover material.

ULTIMATE USE OF CLOSED DUMP

A closed dump need not remain an unused parcel of wasteland. The site may have been changed from a ravine or gully to a relatively flat area. It is no longer unsightly since it is covered with soil and with grass and other vegetation. It is almost inevitable that uneven settlement will be extensive, and recognition of this fact should influence the ultimate use of the site.

In general, it is not advisable to construct buildings over a closed dump because it makes a poor foundation. Furthermore, gas from the decomposing waste may accumulate in explosive concentrations in or beneath buildings constructed on or adjacent to the fill. Playgrounds, golf courses, and similar recreational facilities do not normally have to support appreciable concentrated loads, and converted dumps are often used for these purposes, but they still require careful planning. Maintenance costs may be greater for recreational areas constructed on dumps than on natural ground because of excessive and irregular settling and possible cracking of the cover material.

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Appendix D

Hazardous Wastes

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Increasingly, environmental managers at all levels of government will be required to make decisions on how to cope with hazardous wastes. A brief and simple definition of a hazardous waste, for purposes of this document, would encompass those wastes which cannot or should not be handled or disposed of in the same manner as the community's normal residential solid waste load. The determination of whether a waste is hazardous would stem from a judgment that a significant potential exists for causing adverse public health or environmental impacts if the waste is handled, stored, transported, treated, or disposed of in the manner generally accepted for ordinary solid wastes.

General categories of hazardous waste are toxic chemical, flammable, radioactive, explosive, and biological. Such wastes can take the form of solids, sludges, liquids, or gases. There is no "master list" of substances or compounds which are hazardous when placed onto or under the land. However, work done by and for the Office of Solid Waste Management Programs has identified a number of likely candidates (Table 38). Numerous wastes contain such compounds in quantities which render the waste unacceptable for normal methods of waste management.

THE PROBLEM

Hazardous wastes comprise only a small fraction of the nation's solid wastes. The environmental impact of hazardous wastes, however, is out of all proportion to the amounts because of the threats of severe health and environmental effects, both chronic and acute.

EPA estimates that the generation of nonradioactive hazardous waste is approximately 10 million tons per year. About 40 percent by weight of these wastes are inorganic materials, 60 percent organic. It is also estimated that 90 percent of hazardous waste exists in liquid or in semiliquid form.

At the present, there is no Federal legislation and very few State or local statutes regulating the disposal of hazardous waste on land. To fill this gap, EPA has proposed the Hazardous Waste Management Act of 1973. Other bills of similar nature have also been introduced in the Congress recently. It is hoped that one of these bills will be enacted into law shortly.

As enforcement of the Clean Air Act, the Federal Water Pollution Control Act, and the "Ocean Dumping" Act closes off the air and the water as places in which to dispose of this waste, communities are going to feel the pressure of waste generators disposing of it on the only place left—the land. State and local governments, then, have to be aware of the problem of what hazardous wastes are and of what can and cannot be done with them without threatening the public health or insulting the environment.

The problem of environmental insults caused by improper land disposal of hazardous waste is widespread. EPA has on record a large number of such incidents, of which the following are representative samples:

- As a result of the burial of lead arsenate pesticide in Minnesota over 30 years ago, 13 people were hospitalized with arsenic poisoning in 1972. The poisonings were traced to ingestion of water from wells near the pesticide burial site.
- For several years, a large municipal landfill in Delaware accepted both domestic and industrial wastes. In 1968, this disposal site had to be closed because chemical and

TABLE 38

A SAMPLE LIST OF NONRADIOACTIVE HAZARDOUS COMPOUNDS*

Miscellaneous Inorganics

- Ammonium chromate
- Ammonium dichromate
- Antimony pentafluoride
- Antimony trifluoride
- Arsenic trichloride
- Arsenic trioxide
- Cadmium (alloys)
- Cadmium chloride
- Cadmium cyanide
- Cadmium nitrate
- Cadmium oxide
- Cadmium phosphate
- Cadmium potassium cyanide
- Cadmium (powdered)
- Cadmium sulfate
- Calcium arsenate
- Calcium arsenite
- Calcium cyanides
- Chromic acid
- Copper arsenate
- Copper cyanides
- Cyanide (ion)
- Decaborane
- Diborane
- Hexaborane
- Hydrazine
- Hydrazine azide
- Lead arsenate
- Lead arsenite
- Lead azide
- Lead cyanide
- Magnesium arsenite
- Manganese arsenate
- Mercuric chloride
- Mercuric cyanide
- Mercuric diammonium chloride
- Mercuric nitrate
- Mercuric sulfate
- Mercury
- Nickel carbonyl
- Nickel cyanide
- Pentaborane-9
- Pentaborane-11
- Perchloric acid (to 72%)
- Phosgene (carbonyl chloride)
- Potassium arsenite
- Potassium chromate
- Potassium cyanide
- Potassium dichromate
- Selenium
- Silver azide
- Silver cyanide
- Sodium arsenate
- Sodium arsenite
- Sodium bichromate
- Sodium chromate
- Sodium cyanide
- Sodium monofluoroacetate
- Tetraborane
- Thallium compounds
- Zinc arsenate
- Zinc arsenite
- Zinc cyanide

Halogens and Interhalogens

- Bromine pentafluoride
- Chlorine
- Chlorine pentafluoride
- Chlorine trifluoride
- Fluorine
- Perchloryl fluoride

Miscellaneous Organics

- Acrolein
- Alkyl leads
- Carcinogens (in general)
- Chloropicrin
- Copper acetylide
- Copper chlorotetrazole
- Cyanuric triazide
- Diazodinitrophenol (DDNP)
- Dimethyl sulfate
- Dinitrobenzene
- Dinitro cresols
- Dinitrophenol
- Dinitrotoluene
- Dipentaerythritol hexanitrate (DPEHN)
- GB (propoxy (2)-methylphosphoryl fluoride)
- Gelatinized nitrocellulose (PNC)
- Glycol dinitrate
- Gold fulminate
- Lead 2,4-dinitroresorcinate (LDNR)
- Lead styphnate
- Lewisite (2-chloroethenyl dichloroarsine)
- Mannitol hexanitrate
- Nitroaniline
- Nitrocellulose
- Nitrogen mustards (2,2',2" trichlorotriethylamine)
- Nitroglycerin
- Organic mercury compounds
- Pentachlorophenol
- Picric acid
- Potassium dinitrobenzfuroxan (KDNBF)
- Silver acetylide
- Silver tetrazene
- Tear gas (CN) (chloroacetophenone)
- Tear gas (CS) (2-chlorobenzylidene malononitrile)
- Tetrazene
- VX (ethoxy-methyl phosphoryl N,N dipropoxy-(2-2), thiocholine)

Organic Halogen Compounds

- Aldrin
- Chlorinated aromatics
- Chlordane
- Copper acetoarsenite
- 2,4-D (2,4-dichlorophenoxyacetic acid)
- DDD
- DDT
- Demeton
- Dieldrin
- Endrin
- Ethylene bromide
- Fluorides (organic)
- Guthion
- Heptachlor
- Lindane
- Methyl bromide
- Methyl chloride
- Methyl parathion
- Parathion
- Polychlorinated biphenyls (PCB)

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* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Report to Congress; disposal of hazardous wastes. Environmental Protection Agency Publication No. SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

biological contaminants had leached into the groundwater. By 1974, this incident had affected the drinking water supply of over 40,000 area residents; their water is presently provided by alternate sources. The cleanup costs are estimated to be up to $10 million.

- For 20 years, a laboratory in Iowa used a particular site for solid waste disposal.

Over 250,000 cubic feet of arsenic-bearing wastes have been deposited there. Monitoring wells around the dump have established that there is over 175 ppm arsenic in the groundwater. The U.S. Public Health Service drinking water standard for arsenic is 0.05 ppm. The dump site is located above a limestone bedrock aquifer from which 70 percent of the nearby city's residents obtain their drinking and crop irrigation water. Although there is no evidence that the drinking water is being affected, the potential for contamination cannot be underestimated.

- A Tennessee chemical company for a number of years was burying highly toxic pesticide wastes at a dump in shallow unlined trenches, at the rate of about a hundred 55-gallon steel drums per week. The containerized chlorinated hydrocarbon wastes gradually escaped into the subsurface environment, contaminating not only the groundwater but also a nearby creek.

HAZARDOUS WASTE SOURCES

Sources of hazardous wastes are numerous and scattered throughout the country. Obvious ones are industry, certain Federal facilities (chiefly the Department of Defense and the Atomic Energy Commission), agricultural activities (see below for recommended procedures for pesticide disposal), hospitals, and laboratories. It is estimated, however, that most hazardous wastes are generated by industrial sources.

Representative hazardous substances have been matched with industrial sources (Table 39). There are many other industrial hazardous waste generating sources, however.

According to a rough geographic distribution of industrial hazardous waste generation, about 70 percent of industrial hazardous waste is generated in the Mid-Atlantic, Great Lakes, and Gulf Coast areas of the United States (Table 40).

TREATMENT AND DISPOSAL TECHNOLOGY

As concluded in EPA's 1973 report to Congress on hazardous waste disposal, technology for the proper treatment and disposal of hazardous waste is generally available. However, the lack of regulation and economic incentive discourages the use of environmentally acceptable treatment and land disposal methods.

TABLE 39

PRESENCE OF REPRESENTATIVE HAZARDOUS SUBSTANCES IN WASTE STREAMS OF SELECTED INDUSTRIES *

Industry	Hazardous substances										
	As	Cd	Chlorinated hydrocarbons †	Cr	Cu	Cyanides	Pb	Hg	Miscellaneous organics ‡	Se	Zn
Mining and metallurgy	x	x		x	x	x	x	x		x	x
Paint and dye		x		x	x	x	x	x	x	x	
Pesticide	x		x			x	x	x	x		x
Electrical and electronic			x		x	x	x	x		x	
Printing and duplicating	x			x	x		x		x	x	
Electroplating and metal finishing		x		x	x	x					x
Chemical manufacturing			x	x	x			x	x		
Explosives	x				x		x	x	x		
Rubber and plastics			x			x		x	x		x
Battery		x					x	x			x
Pharmaceutical	x							x	x		
Textile				x	x				x		
Petroleum and coal	x		x				x				
Pulp and paper								x	x		
Leather				x					x		

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* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Report to Congress; disposal of hazardous wastes. Environmental Protection Agency Publication No. SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

† Including polychlorinated biphenyls.

‡ For example, acrolein, chloropicrin, dimethyl sulfate, dinitrobenzene, dinitrophenol, nitroaniline, and pentachlorophenol.

TABLE 40

ESTIMATED INDUSTRIAL HAZARDOUS WASTE GENERATION BY BUREAU OF CENSUS REGION, 1970 *

Region	Inorganics in aqueous		Organics in aqueous		Organics		Sludges, † slurries, solids		Total		Percent of total
	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	
New England	95,000	86,000	170,000	154,000	33,000	30,000	6,000	5,450	304,000	275,450	3.1
Mid Atlantic	1,000,000	907,200	1,100,000	1,000,000	105,000	90,600	55,000	50,000	2,260,000	2,047,800	22.9
East North Central	1,300,000	1,180,000	850,000	770,000	145,000	132,000	90,000	81,600	2,385,000	2,163,600	24.2
West North Central	65,000	59,000	260,000	236,000	49,500	45,000	18,500	16,800	393,000	350,800	4.0
South Atlantic	230,000	208,500	600,000	545,000	75,000	68,000	80,000	72,600	985,000	894,100	10.0
East South Central	90,000	81,700	385,000	350,000	44,000	40,000	9,500	8,600	528,000	480,300	5.4
West South Central	320,000	290,000	1,450,000	1,315,000	180,000	163,000	39,000	35,400	1,989,000	1,803,400	20.2
West (Pacific)	120,000	109,000	550,000	500,000	113,000	103,000	30,500	27,700	813,500	739,770	8.3
Mountain	125,000	113,500	5,000	4,540	50,000	45,400	11,500	10,400	191,500	173,840	1.9
Total	3,345,000	3,034,900	5,370,000	4,874,540	794,500	717,000	340,000	308,620	9,849,500	8,929,060	100.0

* Source: BATTELLE PACIFIC NORTHWEST LABORATORIES. Program for the management of hazardous wastes. Vols. 1 and 2. U.S. Environmental Protection Agency. (Available through the National Technical Information Service, Springfield, Va.) (In press.)

† Predominantly inorganic.

Treatment processes for hazardous waste should perform the following functions: volume reduction, component separation, detoxification, materials recovery.

No single process can perform all these functions; a series of several processes are generally required for adequate treatment.

The general applicability of various treatment processes to types and forms of hazardous waste has been determined (Table 41). Many of these processes have been utilized previously for managing hazardous waste in industry and government. Several processes have capabilities for resource recovery. Selection of appropriate methods depends upon the type, form, and volume of the waste, and the relative economics of the processes.

WHAT TO DO WITH HAZARDOUS WASTES

Those wastes which cannot be disposed of safely in ordinary landfills should receive adequate treatment to render them nonhazardous prior to disposal. A small private hazardous waste management industry has emerged in the last decade, offering treatment and disposal services to generators. A preliminary compilation has been made of firms that are in the business of accepting hazardous waste for disposal (see list at end). The list will be expanded from time to time as OSWMP becomes aware of other service companies of this nature. Information on the availability of additional service companies is hereby solicited. It should be emphasized that EPA cannot endorse or vouch for the environmental adequacy of the work of the firms cited.

Requests for further information and technical assistance which relate to management of hazardous wastes should be directed to OSWMP's Hazardous Waste Management Division or to the Solid Waste Management Representative in EPA's Regional Offices.

PESTICIDE DISPOSAL AND STORAGE

The potential seriousness of health and environmental hazards due to improper disposal and storage of pesticides and their containers became increasingly clear in the late 1960's as documented case studies accumulated. Expanding use of pesticides in the United States (an estimated 665 million pounds in 1968) and increasing numbers of spent containers requiring disposal (240 million in 1968, up 50 percent over the number in 1963) indicated that these problems were increasing. Since little was known of the extent of the problem, or proper methods of disposal and storage, the Working Group on Pesticides, composed of representatives from several Federal departments, was asked to study the subject.

More recently, in 1972, a Task Force on Excess Chemicals, with representation from all parts of the Environmental Protection Agency, was formed to study disposal problems relating to pesticides and other hazardous chemicals, and to recommend solutions. Using the knowledge and information gathered by these two groups, as well as by other Federal and State agencies and the private sector, EPA drew up recommended procedures for the disposal of pesticides. These recommended procedures were proposed in

TABLE 41

FUNCTIONS, APPLICABILITY, AND RESOURCE RECOVERY CAPABILITY OF CURRENTLY AVAILABLE HAZARDOUS WASTE TREATMENT AND DISPOSAL PROCESSES *

Process	Functions performed †	Types of waste ‡	Forms of waste §	Resource recovery capability
Physical treatment:				
Carbon sorption	VR, Se	1, 3, 4, 5	L, G	Yes
Dialysis	VR, Se	1, 2, 3, 4	L	Yes
Electrodialysis	VR, Se	1, 2, 3, 4, 6	L	Yes
Evaporation	VR, Se	1, 2, 5	L	Yes
Filtration	VR, Se	1, 2, 3, 4, 5	L, G	Yes
Flocculation/settling	VR, Se	1, 2, 3, 4, 5	L	Yes
Reverse osmosis	VR, Se	1, 2, 4, 6	L	Yes
Ammonia stripping	VR, Se	1, 2, 3, 4	L	Yes
Chemical treatment:				
Calcination	VR	1, 2, 5	L	
Ion exchange	VR, Se, De	1, 2, 3, 4, 5	L	Yes
Neutralization	De	1, 2, 3, 4	L	Yes
Oxidation	De	1, 2, 3, 4	L	
Precipitation	VR, Se	1, 2, 3, 4, 5	L	Yes
Reduction	De	1, 2	L	
Thermal treatment:				
Pyrolysis	VR, De	3, 4, 6	S, L, G	Yes
Incineration	De, Di	3, 5, 6, 7, 8	S, L, G	Yes
Biological treatment:				
Activated sludges	De	3	L	No
Aerated lagoons	De	3	L	No
Waste stabilization ponds	De	3	L	No
Trickling filters	De	3	L	No
Disposal/storage:				
Deep-well injection	Di	1, 2, 3, 4, 6, 7	L	No
Detonation	Di	6, 8	S, L, G	No
Engineered storage	St	1, 2, 3, 4, 5, 6, 7, 8	S, L, G	No
Land burial	Di	1, 2, 3, 4, 5, 6, 7, 8	S, L	No
Ocean dumping	Di	1, 2, 3, 4, 7, 8	S, L, G	No

* Sources: TRW SYSTEMS GROUP. Recommended methods of reduction, neutralization, recovery or disposal of hazardous waste. Vol. 1-16. Springfield, National Technical Information Service, 1973. PB-224 579-set/AS. ARTHUR D. LITTLE, INC. Alternatives to the management of hazardous wastes at national disposal sites. Vols. 1 and 2. U.S. Environmental Protection Agency, 1973. Available from National Technical Information Service, Springfield, Va., as PB-225 164 AS. BATTELLE PACIFIC NORTHWEST LABORATORIES. Program for the management of hazardous wastes. Vols. 1 and 2. U.S. Environmental Protection Agency. (Available through the National Technical Information Service, Springfield, Va.) (In press.)

† Functions: VR, volume reduction; Se, separation; De, detoxification; Di, disposal; and St, storage.

‡ Waste types: 1, inorganic chemical without heavy metals; 2, inorganic chemical with heavy metals; 3, organic chemical without heavy metals; 4, organic chemical with heavy metals; 5, radiological; 6, biological; 7, flammable; and 8, explosive.

§ Waste forms: S, solid; L, liquid; and G, gas.

the *Federal Register* of May 23, 1973, with the intent to elicit public comments, and promulgated in final form May 1, 1974.

The Procedures and Their Applicability

EPA's recommended procedures represent broadly based judgments regarding the disposal and storage requirements for pesticides and their containers that are necessary to protect the environment. Compliance is achievable using existing technology; however, facilities utilizing this technology are not readily available in all geographic areas.

The recommended disposal procedures apply to all pesticides and pesticide-related wastes, including those which are or may in the future be registered for general use or restricted use, or used under an experimental use permit. Additionally, they also apply to full containers, spent or used containers, and container residues. For packages and containers of pesticides intended for use in the home and garden or when single containers are to be disposed of on farms and ranches, the Agency does not require that these disposal procedures be followed. Disposal of such items will have only minimal environmental impact, and it is preferable to dispose of them individually rather than concentrate them.

The storage criteria and procedures apply to pesticides, pesticide-related wastes, and contaminated containers which are classified as "highly toxic" (DANGER, POISON) or "moderately toxic" (WARNING) according to EPA's classification system for pesticides. The storage of pesticides and their containers which are in the mildly toxic category is judged not to present any undue hazards to public health or the environment and, therefore, is excluded from the procedures. The temporary storage of limited quantities of pesticides in the other categories, if undertaken at environmentally safe sites, is also excluded.

Disposal Methods

First preference in considering disposal techniques should be given to procedures designed to recover some useful value from excess pesticides and containers. Where large quantities are involved, one of the first recommendations is that the excess material should be used for the purpose originally intended, provided this use is legal. Another alternative is to return the material to the manufacturer for potential reuse or reprocessing. A third alternative may be the export of the material to countries where its use is desired and legal.

Should none of these alternatives be applicable, the ultimate disposal method should be determined by the type of hazardous material involved. Organic pesticides which do not contain mercury, lead, cadmium, arsenic, beryllium, selenium, or other toxic materials may be disposed of by incineration at temperatures which will ensure complete destruction. Maximum volume reduction is achieved by incineration, and the incinerator emissions can be treated so that only relatively innocuous products are emitted. Incineration is not, however, applicable to those organic pesticides which contain heavy metals such as mercury, lead, cadmium, or arsenic, nor is it applicable to most inorganic pesticides or metallo-organic pesticides which have not been treated for removal of heavy metals. Metallo-organic pesticides may be incinerated after treatment to remove the metal or metalloid atoms from the hydrocarbon structure.

If incineration is not applicable or available, disposal in specially designated landfills is suggested as an alternative. However, encapsulation prior to landfilling is recommended for certain materials such as those containing mercury, lead, cadmium, arsenic, beryllium, selenium, or other toxic materials and all inorganic compounds which may be highly mobile in the soil. Encapsulation of these will retard mobility and contain them within a small area which can be permanently marked and recorded for future reference.

Other disposal processes, such as soil injection, well injection, and chemical degradation, may be acceptable in certain areas for some materials. At present, such methods have been neither sufficiently described nor classified to suggest their general use. Regional Offices of EPA may be contacted for advice on specific areas.

Among the disposal procedures not acceptable are water/ocean dumping, open dumping, and open burning, except that open burning of small quantities of certain containers (if legal) and open field burial of single containers on farms and ranches by the pesticide user may be acceptable in some areas.

EPA's recommended triple rinsing procedure will clean containers well enough so that insignificant contamination will occur when such containers are legally refilled with another pesticide belonging to the same chemical class. Triple rinsing also prepares containers for crushing or shredding and recycling as scrap. Provisions for this resource conservation step have been included in the recommended procedures; they specifically require that adequate rinsing be undertaken before reuse or recycling of containers.

Storage

Storage sites and facilities should be located and constructed to prevent escape of pesticides and contaminated materials into the environment. Provision for separate storage of different classifications of pesticides according to their chemical type, and for routine container inspection, should be considered. Special procedures should be followed in case of fires or explosions, and the fire and police officials should be provided with the names and telephone numbers of the persons responsible for each pesticide storage facility.

These recommended procedures are designed to alert all Federal, State, and local government agencies and private manufacturers, handlers, and users of pesticides to the need for proper disposal and storage of excess pesticides, pesticide containers, and pesticide-related wastes. The U.S. Environmental Protection Agency will conform to these recommended procedures in its own operations. State and local agencies are cautioned against adoption of recommended procedures as regulations without careful study of the environmental and economic factors applicable to their own situations, including the availability of disposal sites and facilities.

HAZARDOUS WASTE DISPOSAL OPERATIONS *

Preliminary Listing

May 15, 1974

The following enterprises are in the business of accepting and disposing of various hazardous wastes. It is to be emphasized that the Office of Solid Waste Management Programs does not endorse any of these firms; moreover, OSWMP did *not* investigate these operations and therefore cannot vouch for their environmental adequacy. This list, which is furnished as a public service, will be expanded from time to time as OSWMP becomes aware of other enterprises that accept hazardous wastes for disposal. Additional information concerning these and other facilities should be forwarded to Mr. Albert Hayes, Hazardous Waste Management Division (HM-565), OSWMP, EPA, Washington, D.C. 20460, or to the OSWMP representative of the appropriate EPA Regional Office.

Those wishing to make use of the services of these firms are advised to first evaluate the available environmental control facilities for themselves. Facilities disposing of pesticides or pesticide containers should conform to the "Recommended Procedures for the Disposal and Storage of Pesticides and Pesticide Containers," as published by EPA in the *Federal Register*. Those utilizing incineration or landfilling should conform to EPA's landfill and incineration guidelines and to any applicable State or local regulations.

With regard to the list itself be aware that: (a) where "materials handled" is unspecified, the assumption is that all waste is received; (b) where branch facilities are known they are also presented individually in their respective localities.

EPA REGION I

Massachusetts

Development Science, Inc.
East Sandwich, Mass.
Facility: computer systems operation
Function: acts as a clearinghouse for information on disposal of waste and surplus chemicals
Telephone: (617) 888-0101

The following list provided by the Massachusetts Water Resources Commission shows all operations which have been licensed for hazardous waste collection by the State. Currently more complete addresses and telephone numbers are not known but a survey will be made to obtain this information.

Company	*Material* †	*Facilities*
Ahearn Trucking Co. Chicopee, Mass.	A B C E	
Andy's Disposal Boston, Mass.	A B	

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* Mainly these are private firms, but some publicly owned operations are also included.

† Classes of hazardous waste: A, waste oils; B, solvents and chlorinated oils; C, toxic metals and plating wastes; D, explosives and reactive metals; E, hazardous chemical, biological, and radioactive waste.

EPA REGION I (*Continued*)

Company	*Material*	*Facilities*
Axton-Cross Co. Holliston, Mass.	A B C E	
Cal's Enterprise Berkeley, Mass.	A B C E	
Cannons Engineering Corporation Boston, Mass.	A B	Storage, incineration
Chemical Application Company Beverly, Mass.	A E	
Coastal Services, Inc. Braintree, Mass.	A B	Storage
Crago Company, Inc. Gray, Maine	A B	
Eastern Contract Disposal Rowley, Mass.	A B C E	
Environmental Ecology Emulation Corporation South Boston, Mass.	A B	
Farrar Pumping Company Abington, Mass.	C	
General Chemical Corporation Framingham, Mass.	B	
Charles George Land Reclamation Trust Tyngsboro, Mass.	A C E	
John R. Hess & Sons, Inc. Cranston, Rhode Island	B	
Interex Corporation Waltham, Mass.	E	Radioactive waste
Jet Line Services Braintree, Mass.	A	Storage facility in Stoughton, Mass.
Montvale Laboratories Inc. Stoneham, Mass.	A B C E	Chlorinated solvent reclaiming facility
Peirce Brothers Oil Service, Inc. Waltham, Mass.	A B	Storage facility in Dorchester, Mass.
Re-Solve, Incorporated Dartmouth, Mass.	B	Solvent reclaiming facility
Rollins Environmental Services Bridgeport, N.J.	A B C E	Treatment and incineration facility
Safety Projects and Engineering Incorporated West Quincy, Mass.	B D E	Storage facility in Hingham, Mass.
Silresim Chemical Corporation Lowell, Mass.	A B C E	Chlorinated solvent reclaiming facility
Southampton Sanitary Engineering Company Southampton, Mass.	A B	
H. Tremblay Co., Inc. Hatfield, Mass.	A E	

EPA REGION I (*Continued*)

Corporations Licensed for Disposal of Own Hazardous Wastes

Bay State Abrasives Division of Dresser Industries, Incorporated Westboro, Mass.	A	Dewatered sludge landfilled
Columbia Manufacturing Co. Westfield, Mass.	C	Dewatered sludge landfilled
General Electric Company Lynn, Mass. Pittsfield, Mass.	A B C E	Collection between GE plants. Incinerators in Pittsfield and Lynn
Raytheon Company Lowell, Mass.	C E	Transportation from Raytheon plant
Spalding Company Chicopee, Mass.	C	Dewatered sludge landfilled
Sprague Electric Company North Adams, Mass.	A B E	Dewatered sludge landfilled
L. S. Starrett & Company Athol, Mass.	C	Dewatered sludge landfilled
Ventron Corporation Beverly, Mass.	C D	Collection between Ventron plants

EPA REGION II

Delaware

AENCO Inc.
Post Office Box 387
New Castle, Del.
(302) 328-136

Rollins Environmental Services, Inc.
3208 Concord Pike
Wilmington, Del. 19899
(302) 658-8541
Facilities: Bridgeport, New Jersey; Baton Rouge, Louisiana; Houston, Texas
Materials handled: liquids and slurries only

New Jersey

Astropak Corporation
Post Office Box 416
Edison, N. J. 08817
(201) 549-1788

Chemical Control Corporation
Elizabeth, N.J.
(201) 351-5460

Industrial Surplus Chemical
Edison, N.J.

Modern Transportation Company
Kearny, N.J.

Rollins Environmental Services, Inc.
(branch facility)
Bridgeport, N.J.

Scientific Chemical Treatment
Elizabeth, N.J.

Scientific Pollution Control Company
Saddle River, N.J.

New York

Chem-Trol Pollution Services, Inc.
Post Office Box 200
Model City, N.Y. 14107
(716) 754-8231
Facilities: landfill and incineration

Nuclear Fuel Services Disposal
Cataraugus, N.Y.
West Valley, N.Y.
(716) 942-3235
Materials handled: nuclear wastes only

EPA REGION II (*Concluded*)

Mercury Refining Company, Inc.
Albany, N.Y.
Contact: Mr. Leo Cohen
(518) 489-7363

Northeastern Maintenance Services
Schenectady, N.Y.

Pollution Abatement Services
Post Office Box 4065
Oswego, N.Y. 13126

Recycling Laboratories, Inc.
112 Harrison Place
Syracuse, N.Y. 13202
(315) 422-4311
Facilities: distillation for recycling
Materials handled: solvents only

EPA REGION III

Maryland

American Recovery Corporation
2001 Bonhill Avenue
Baltimore, Md. 21226

Robb Tyler Inc.
Norris Farm Landfill
New Pulaski Highway and 66th Street
Baltimore, Md. 21237

Pennsylvania

Barclay Cleaning Industries
Allentown, Pa.

Bethlehem Apparatus Company, Inc.
Front and Depot Streets
Hellerton, Pa. 18055
(215) 838-7034

Chemfix Corporation
(Branch of Environmental Services Inc.)

EPA REGION III (*Concluded*)

2901 Banksville Road
Pittsburgh, Pa. 15216
(412) 343-8611

Interstate Oil Transport
Penn Center
Philadelphia, Pa.

King of Prussia Technical Company
King of Prussia, Pa.

McAllister Brothers
Mall Building
Philadelphia, Pa.

Richard Welch
87 Longview Drive
Churchville, Pa. 18966
(215) 357-9159

Sitkin Metal Industries, Inc.
Post Office Box 708
Lewistown, Pa.

University of Pittsburgh
Dr. June Phister
Bradford Branch Campus
Bradford, Pa.

EPA REGION IV

Kentucky

Liquid Waste Disposal, Inc.
Post Office Box 19063
Louisville, Ky. 40219
Contact: Mr. G. M. O'Bryon
(502) 968-6173
Facilities: high temperature incineration
Materials handled: liquids only

Nuclear Engineering Company, Inc.
Post Office Box 7246
Louisville, Ky. 40207
(502) 426-7160
Contact: Mr. Barney Roberts
Site locations:
  Beatty, Nev.
  Sheffield, Ill.
  Robstown, Texas (Texas Ecologists, Subsidiary)
Materials handled: liquids, slurries, sludges, containers, solids

South Carolina

Chem Nuclear Systems Inc.
Barnwell, S.C.
(803) 259-5983
Materials handled: primarily radioactive

EPA REGION V

Illinois

Hyon Waste Treatment Services
Chicago, Ill. 60617
Contact: Mr. Dave Holland
(312) 646-0016
Facilities: rotary kiln incinerator
Materials handled: solids and semisolids

Nuclear Engineering Company, Inc.
Sheffield, Ill.

Indiana

Conservation Chemical Company
Gary, Ind.

Seymour Manufacturing Company
500 North Broadway

EPA REGION V (*Concluded*)

Seymour, Ind.
Contact: Mr. John Gregory
(802) 522-4051
Facilities: physical-chemical treatment, incineration, recycle
Materials handled: liquids only

Michigan

Environmental Waste Control Incorporated
26705 Michigan Avenue
Inkster, Mich. 48141
Contact: Mr. Hornby
(313) 357-5680
Facilities: processing, recovery, decontamination
Materials handled: oils, acids, alkalines, cyanides, pickling liquors

Land and Lakes Environmental Company
Division of Approved Industrial Removal Incorporated
3755 Linden, South East
Grand Rapids, Mich. 49608
(616) 452-6021

Liquid Disposal Company
Utica, Mich.
(313) 739-2727
Facilities: incinerator

Nelson Chemical Company
12345 Schaefer Highway
Detroit, Mich. 48227
Contact: Mr. Hammerstein
(313) 933-1500
Facilities: processing and landfill
Materials handled: cyanides, chromic acid, pickling liquors

Minnesota

Pollution Controls Incorporated
Route 1
Post Office Box 1057
Shakopee, Minn. 55379
Contact: Mr. Knutson
(612) 645-5507
Facilities: incinerator
Materials handled: liquids and solids except mercury, arsenic, and cadmium compounds

Waste Disposal Engineering Sanitary Landfill
Anoka County, Minn.

Ohio

Systems Technology Corporation
Systech
3131 Encrete Lane
Dayton, Ohio 45439
(513) 298-1467

Wisconsin

Rogers Laboratories
3000 South 6th Street
Milwaukee, Wis.
(414) 183-3000

Waste Research and Reclamation Company, Inc.
Eau Claire, Wis.
Facilities: recycling
Materials handled: solvents, oils, forging compounds

EPA REGION VI

Louisiana

Rollins Environmental Services, Inc.
Baton Rouge, La.

EPA REGION VI (*Continued*)

Oklahoma

Royal H. Hardage Industrial Hazardous Waste Land Disposal Site
R.R. 2
Lindsay, Okla. 73052
(405) 344-6274

Texas

Aztec Mercury
Post Office Box 1676
Alvin, Tex. 77511
(713) 331-4141

Bioecology Systems Inc.
4001 East Jefferson
Grand Prairie, Tex. 75050
(214) 264-4281

Rollins Environmental Services, Inc.
Houston, Tex.

Texas Ecologists, Inc.
Subsidiary of Nuclear Engineering Company
Robstown, Tex.

EPA REGION VII

Missouri

Conservation Chemical Company
Kansas City, Mo.
(816) 483-4222
Facilities: Kansas City and St. Louis

Monsanto Company
800 North Lindbergh Boulevard
St. Louis, Mo. 63166
(314) 694-3352
Facilities: incinerator
Materials handled: primarily PCB's

EPA REGION IX

California

B.K.K. Corporation
3031 East I Street
Wilmington, Calif. 90744
Contact: Mr. Ben K. Kazarian
(213) 432-8461
Facilities: Landfill at West Covina, Calif.
Materials handled: liquids, slurries, sludges, and containers

Casmalia Disposal Site
Post Office Box 5275
Santa Barbara, Calif. 93108
Contact: Mr. K. R. Hunter, Jr.
(805) 969-4703
Facilities: landfill near Guadalupe, Calif.
Materials handled: liquids, sludges, and containers

Chancellor and Ogden, Inc.
Total Transport/Disposal System
3031 East I Street
Wilmington, Calif. 90744
Contact: Mr. William Shearer
(213) 596-3049

Chemical Buyers Service
Post Office Box 2065
Berkeley, Calif. 94702
Contact: Mr. Joe Cambrey or Paul Palmer
(415) 548-0901, 0941
Facilities: computer-based clearinghouse for recycling of surplus chemicals and wastes

EPA REGION IX (*Continued*)

Materials handled: Chemical-type wastes having potential for reuse

Colusa County Department of Public Works
Courthouse
Colusa, Calif. 95932
(916) 458-5186
Facility: Class II—I site
Materials handled: pesticide containers, general refuse

Environmental Protection Corporation
3905 Rosedale Highway
Post Office Box 2491
Bakersfield, Calif. 93303
(805) 327-9681
Materials handled: limited types of liquids and sludges

Fresno County Department of Public Works
4499 East Kings Canyon Road
Fresno, Calif. 93702
(209) 488-3806
Facilities: landfill in Coalinga, Calif.
Materials handled: liquids, solids, and containers

Hollister Disposal Site
City Hall
375 Fifth Street
San Benito City, Calif.
(408) 637-4491
Materials handled: liquids and solids from county only

Hunter Disposal Site
Post Office Box 5275
Santa Barbara, Calif. 93108
Materials handled: liquids, sludges, pesticide containers

Hutchinson, William H. and Sons, Inc.
217 North Lagoon Avenue
Wilmington, Calif. 90744

Industrial Tank Company
Box 831, 210 Berellesa Street
Martinez, Calif.
Contact: Mr. Victor Johnson
(415) 228-5100
or East 122 G Street
Benicia, Calif.
Facilities: landfills in Pittsburg, Calif., and Martinez, Calif.
Materials handled: liquids and solids except pesticides

J and J Disposal Company
East 122 G Street
Benicia, Calif.
Contact: Mr. H. L. Jenkins
(707) 745-1251
Facilities: landfill
Materials handled: liquids, slurries, and sludges, except pesticides

Los Angeles County Sanitation District
2020 Beverly Boulevard
Los Angeles, Calif. 90057
Contact: Mr. Lester A. Haug
(213) 384-1281
Facilities: landfills at Agoura and Rolling Hills, Calif.
Materials handled: liquids, slurries, sludges, and containers

Nuclear Engineering Company Incorporated
Walnut Creek, Calif.
Contact: Mrs. Sullivan
(415) 933–0770
Facilities: Beatty, Nev., Sheffield, Ill., Morehead, Ky., Robstown, Tex. (Texas Ecologists, Inc., subsidiary)

Omar Rendering Company
Post Office Box 1236
Chula Vista, Calif.
Contact: Mr. William S. O'Donnell
(714) 422–5311
Facilities: warehousing and transport
Materials handled: liquids and slurries only except oils

Richmond Sanitary Service
1224 Nevin Avenue
Richmond, Calif.
Contact: Mr. Mario Aquilino
(415) 234–3304
Facilities: landfill

Materials handled: liquids, slurries, sludges, solids, and containers

San Diego County Refuse Disposal Division
5555 Overland Road
San Diego, Calif.
Contact: Mr. G. G. Baker
(714) 278–9200
Facilities: landfill at Otay, Calif.
Materials handled: liquids, slurries, sludges, and containers except acids

Ventura County Department of Public Works
597 East Main Street
Ventura, Calif.
Contact: Mr. Felix Martinez
(805) 648–6131
Facilities: landfill in Simi Valley, Calif.
Materials handled: liquids, slurries, sludges, and containers

Nevada

Nuclear Engineering Company, Inc.
Beatty, Nev.

μσ 967